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EDITORIAL

THE AMERICAN ASSOCIATION FOR THE SURGERY OF TRAUMA

FIRST PRESIDENTIAL ADDRESS

KELLOGG SPEED, M.D.

CHICAGO, ILLINOIS

WITHOUT attempting to go into the intimate, and soon to be historical, details of the organization of this association, which I hope my successor will do for us next year, it is my desire to set forth in an expositional manner what the principal aims, ambitions and uses of this organization may be and what its future intentions may develop.

In the rapidly expanding field of general surgery several schisms have occurred within the last thirty years, ending in a breaking off of certain specialties and narrowed fields, such as ear, nose and throat surgery, genitourinary surgery, neurologic surgery, thoracic surgery, with others—and even one body devoted quite entirely to the surgery of goiter: It is not the primary desire or intention of the American Association for the Surgery of Trauma to cause the formation of an additional and possibly narrowed-vision group of surgeons under a different label, but to attempt an amalgamation and calling back to the fold of the well trained general surgeon of those interested in the maintenance of high surgical skill and scientific development in the phases of surgery which have to do with trauma, its immediate and distant effects and complications.

As we know or shall learn from the history of our organization, practically all the members are simultaneously members of other

American associations of different branches of surgery or the American Surgical Association itself. The press of time and the limitations of subjects at the annual meeting of many of these organizations has led to a great diminution in the number of papers concerning trauma submitted by title, and almost a complete absence, year after year, of papers of this character really read before the various meetings mentioned. This shoving into the background of trauma and its field in connection with all branches of surgery has not been because everything is known about the subject, but because vital and interesting physiologic studies and advances, coupled with anatomic study and daring have spread into every field of surgical research. This has led to so many reports and outbursts on physio- and chemicosurgical subjects in the literature, some controversial, some rapidly accepted and some patently unsound from their inception, that old fashioned trauma and its connections, forever with us like the poor, have jogged along, unheralded, poorly nourished and yet demanding a large share of hospital service, of operative time and skill in all parts of the world.

To correlate the newer advances and adjustments of surgical study and technique, the surgery of trauma now steps forth and demands recognition. The Association for the Surgery of Trauma has already attracted, and will continue to attract, the brightest surgically inclined minds. Its forum is opened to the problems of all phases of trauma and its consequences without developing any feeling of inferiority complex among essayists and discussers.

In this galaxy of surgical personnel before me, are men well informed in many of the problems of trauma in its connection with the various tissues and parts of the human body. Many of us apply the most advanced physiologic and pathologic information to what may appear a simple instance of trauma affecting our fellow-men. Consider for a moment the scope of this subject—its relation to shock and the mortality of accident, whether acquired by the impact from an automobile or the staggering blow from a surgical operation, possibly elective in character, and not primarily caused by injury. Consider the advance in study of the infections and gross lesions subsequent to trauma, the anatomic and physiologic studies of trauma of the human hand or skull or craniocerebral tissues. The magnitude of the field spreading out before this association becomes apparent and lends dignity to its birth.

These meetings should consequently be on parity with other American associations for surgical study and are intended to allow an outlet for information, practice, theory and research in connec-

tion with the surgery of trauma. They will induce all fellows of this association, as well as those influenced by them in teaching, in hospital contact and professional brotherhood to demand the highest grade of surgical art and practice for the enormous field of traumatic surgery. As I have stated, we aim to coalesce the best of surgical knowledge and practice and have no intention of adding any new board of surgical licensure, but expect each newly elected member to possess a certificate of ability obtained from the American Board of Surgery.

May I quote from the Presidential address of F. W. Rankin before the Southern Surgical Association in 1938: "The three major objectives which, I believe, the progress of modern surgery will demand in the future, are: First, elevation of standards of graduate instruction; second, adequate certification of surgeons; and third, the controlled hospital. Increasing specialization naturally evokes a number of questions: Do we have too many specialists: is specialization being gradually overdone? The answer to this, I think, must essentially be—no, we do not have too many qualified specialists—that is, if we designate as a specialist a member of the profession, who by training and experience will be accepted by his peers as expert in a particular field. There is no substitute for experience and only by prolonged apprenticeship in a given field may anyone become sufficiently qualified to be designated as a specialist."[1]

The American Board of Surgery has adopted a conservative arrangement of training years for the purpose of qualification before it—namely, five years of training after the interne year, three of which are devoted to intensive postgraduate study preceding eligibility for examination before the board. This qualification is useless without two compensating factors, first, recognition of the meaning and character of this qualification by the public, second, a proper and controlled enforcement of these standards of qualification by the hospitals. Appointments to the surgical staff of hospitals should be made solely from those thus qualified, or in the process of qualification, while under supervision.

The American Association for the Surgery of Trauma, most of whose members are diplomates of the American Board of Surgery, offers consequently a high standing forum for discussion of the problems of trauma in surgery and an opportunity to sift the merits of advances devised or reported. It must exert a wide spread influence on hospital standards, postgraduate teaching and oncoming surgeons.

[1] RANKIN, F. W. Presidential Address, Southern Surgical Association. *Ann. Surg.*, 107: 650 (May) 1938.

Its place in the sun of our chosen profession should be assured from the start. Our supreme effort must be properly directed in wise selections of programs, in regular attendance, in earnest contributions and in careful selection of members to succeed us.

It was Hippocrates who said:

"There is no necessity for much study, then, in order to set a broken arm, and in a word, any ordinary physician can perform it; but I am under the necessity of giving the longer directions on this subject, because I know physicians, who have the reputation of being skilled in giving the proper positions to the arm in binding it up, while in reality they are only showing their own ignorance. But many other things in our art are judged of in this manner, for people rather admire what is new, although they do not know whether it be proper or not, than what they are accustomed to, and know already to be proper; and what is strange, they prefer to what is obvious."[1]

[2] HIPPOCRATES. *Medical Classics*, 3: 171 (*Oct.*) 1938.

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ORIGINAL ARTICLES

SKIN AND FASCIA GRAFTING

ADDISON G. BRENIZER, M.D.

CHARLOTTE, NORTH CAROLINA

I AM dealing first, in brief, with the familiar subject of skin grafting and then with the less familiar subject of fascia grafting in some of its uses.

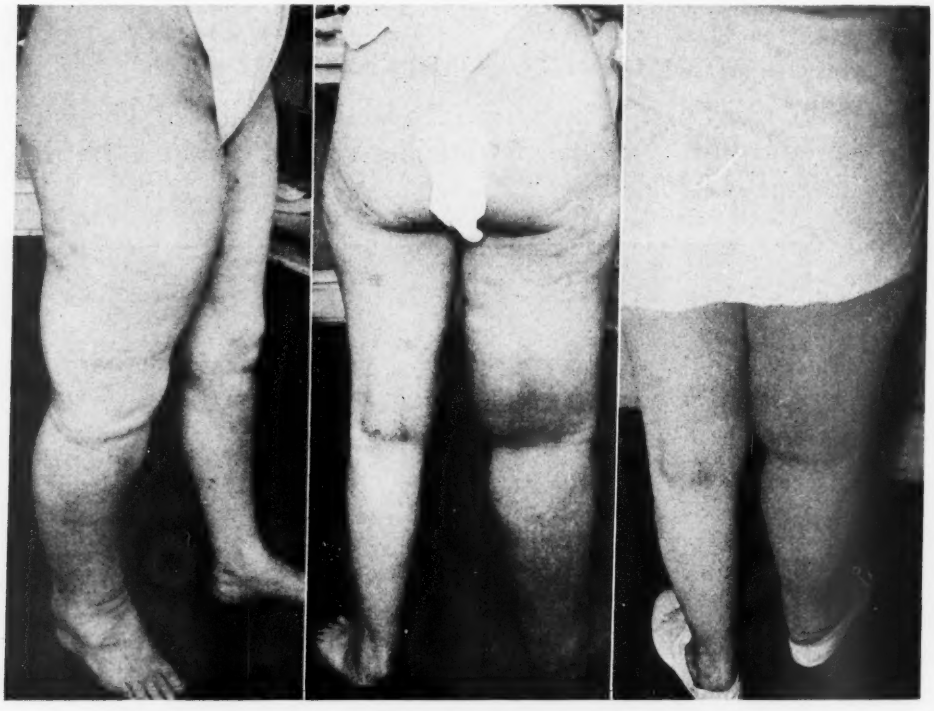
FIG. 1A. Large ulcus cruris grafted with full thickness pinch grafts. Two conditions are important in these cases: (1) tying off the varicose veins, which can be done by ligating them, piercing through the skin without incision; and (2) having fine, closely knit granulations to graft upon.

The oldest and most universally used method of skin grafting is that of Reverdin. Its chief advantages are that it is very easy, requiring nothing more than a straight needle and a razor blade and that the small pinches will remain on surfaces grossly infected. A simple procedure, it can be used on debilitated patients. There are objections, particularly for exposed parts. It gives a mottled or mosaic appearance, is irregular in surface and height on account of the lack of uniformity in cutting and the fact that the small graft itself is cut thicker in the center than at the periphery. There is a

scar around each graft and the method is of little value in the correction of cicatricial contractures. (Fig. 1.)

The very objections to the Reverdin graft may be of advantage, however, as in the following case (Fig. 2):

The patient received a spiral cut around his head, scalping him except for two narrow pedicles. The scalp and skull were cleaned and replaced.

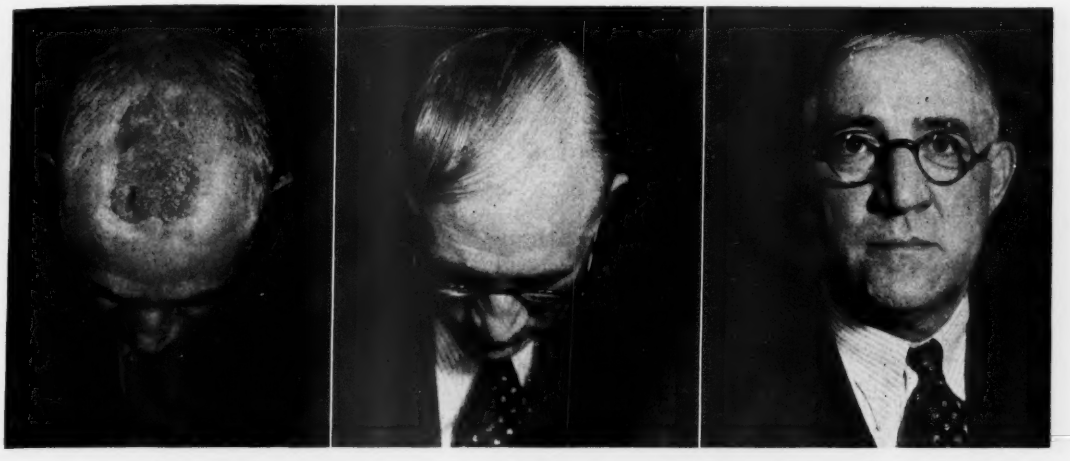


B C D

FIG. 1B, C, and D. A case of lymphangitis before and after a Rogers-Kondoleon operation where long strips of skin were cut from the trochanter to the external malleolus and from the crotch to the internal malleolus. It is essential in these cases to treat the edema of the legs as otherwise the grafts will finally slough away. The edema in leg ulcers is due more to lymphangitis than to phlebitis. Many so-called varicose ulcers require, in preparation for a graft, either a Rogers-Kondoleon or a modified (not so extensive) Kondoleon.

They healed over most of the skull, but on account of poor blood supply, the whole area over the calvaria sloughed, leaving the top of the head bare, down to dry bone. Small holes were drilled through the outer table of the skull and granulations from the diploe allowed to grow up through these holes. The granulating mass was curetted down as the outer table was pushed up and could be removed in large plaques. As the granulations grew and the top was skimmed away with a curette, the depression on top of the head was being filled in, layer-cake-wise. Then Reverdin grafts were taken rather deeply from the patient's very hairy chest. The roughness of the

graft and the stubble of hair put out by the grafts offered a very nice mesh over which he could brush his hair from the side. This held the hair much more securely than a toupee could be placed. I should be very proud to call this "Brenizer's operation for bald head"!



A B C

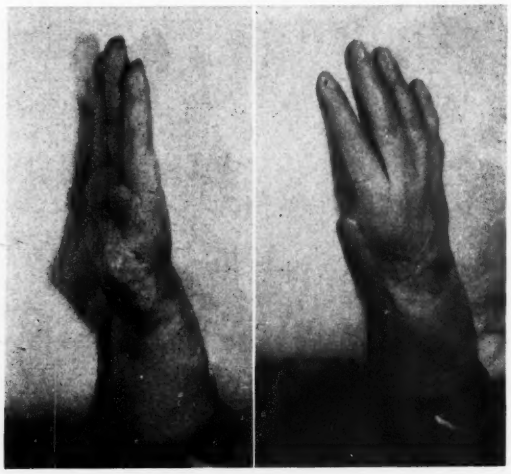
FIG. 2. A, denuded skull grafted with full thickness pinch grafts containing hair follicles. The granulating base is secured by boring small holes through the outer table of the skull, allowing the granulations to grow through the diploe, removing the outer table and repeatedly curetting the granulations until they are built up, layer-cake-wise, to the level of the skin. A small area of outer table has been left and must be removed for complete healing. B, hair brushed over the fine stubble of hair from the pinch grafts. C, front view.

The method described by Ollier in 1882 and Thiersch in 1886 has served us all admirably. Those of us who worked with Halsted were accustomed to cover the denuded area not embraced by the flaps in breast amputations. We found that not only did this area heal well, but the place from which they were taken also healed. However, the skin on the area was thin, the inequalities of the background of muscle and ribs showed through the grafts, and the grafted area contracted and wrinkled. Now, with breast flaps properly and extensively cut, we rarely leave an area not covered or produced by slough that cannot be covered with a few pinch grafts.

It is very difficult to find a perfect material in plastic surgery. However well the operation may be done, the patient invariably thinks that since you have done that well, perhaps if you had been a better surgeon or more careful with his precious flesh, you could have done better.

The full thickness graft described by Wolfe of Glasgow in 1875 was a decided improvement over anything yet offered. The best cosmetic results can be obtained with it and it is therefore used on the face. It stands up well under trauma and offers maximum

mobility over joint surfaces. Such grafts also contract less. Objections, however, there are: Even full thickness skin grafts, like all others, contract somewhat, and most meticulous care must be taken



A B

FIG. 3. A, result of severe automobile accident. Debrided, tendons united and grafted immediately with split skin grafts. B, dorsal view.

A B

FIG. 4. A, twenty years after fascia and bone grafts from tibia had been inserted into a large skull defect, showing perfect result. B, profile.

for their protection against infection. Damage to blood supply and infection will account for many more losses than in the thinner grafts. Cutting the full thickness graft is tedious, the application is difficult because the proper pressure and tension must be attained

and maintained for a period of several weeks. A provision against loss of graft can be made by tunneling or tubing the full thickness graft for the development of better blood supply and the main-

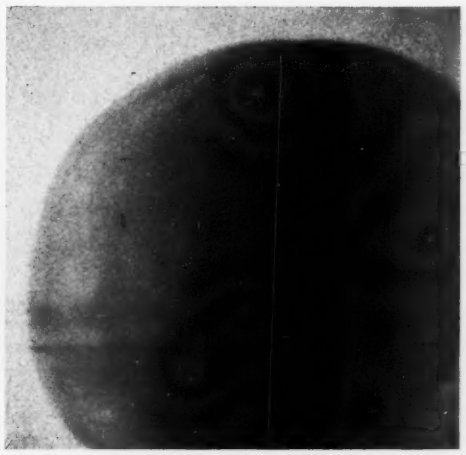


FIG. 4C. *X*-ray of same patient shown in Figure 4. The whole lighter area in the occipital region shows the three large bone shells from the upper tibiae. Indicates how large a defect was covered.

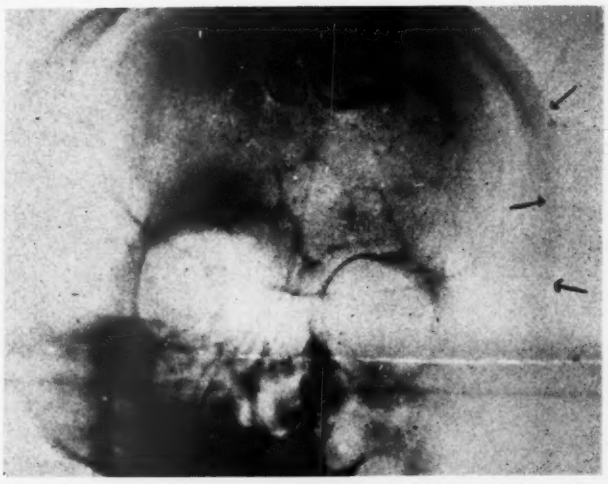


FIG. 5. A much smaller defect filled with bone from the tibia.

tenance of an arterial pedicle. However, there is frequently no choice of method to avoid these tunnels and tubes, though the area of skin is reduced by contracture and the skin in such a shape is more difficult to handle. In burn contractures around the neck restoration of an approximate configuration may be secured by several

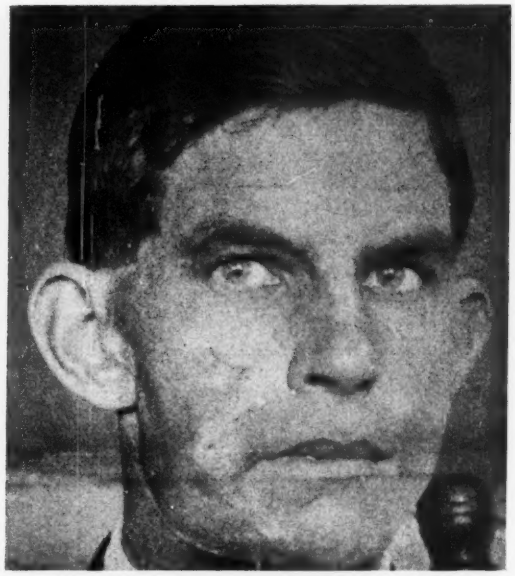


FIG. 6. Shrunken and collapsed cheek resulting from burn, filled in with fascia and fat. Allowance is made for shrinkage of the fat and fascia, but how much allowance to make is guesswork.

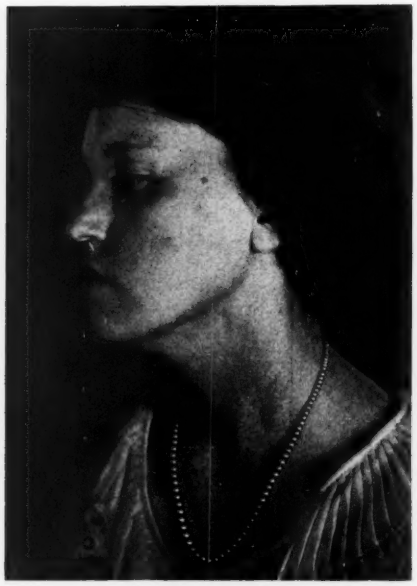


FIG. 7. Paralysis of facial nerve from opening of parotid abscess. The face was lifted with three strips of fascia, run from an incision in the hairline down to the external canthus, the corner of the mouth and the border of the mandible. A marked ectropion of the lower lid was corrected by a suspension strip of fascia from internal to external canthus.

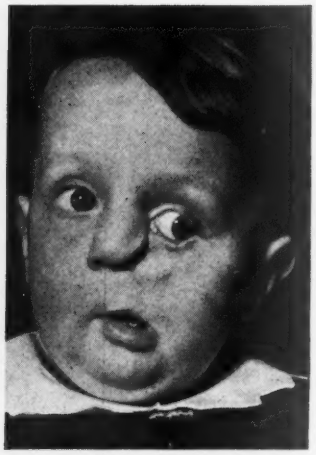


FIG. 8. Child with cleft lip, cheek, palate, jaw and orbit. Soft parts reinforced and held with fascia. (From Brenizer, in *Ann. Surg.*, 107: 692, 1938.)

operations of skin shifting, pedicle grafts, split skin and pinches. Under the chin and in the axilla devices must be used to hold the graft in place.

A B C

FIG. 9. A, harelip. By the use of fascial bands or ribbon catgut, placed between the mucosa and muscularis of the lips, tension is taken off the suture line and the lips may be united with muscle sutures of fine catgut and a subcuticular stitch of fine malleable wire. The soft parts may be placed and maintained in proper configuration with minimum scarring of the lips. The scarring of the mucous membrane readily repairs and is not visible. The slight increase in bulkiness of the lips soon subsides. B, harelip and cleft palate, ribbon catgut being used for repair of both lip and palate. Union, configuration and function all excellent. Lip slightly bulky three weeks after operation. C, good union, configuration and function in harelip and cleft palate; no surface scarring. Deficient right ala and irregularity in vermilion border. (From Brenizer, in *Ann. Surg.*, 107: 692, 1938.)

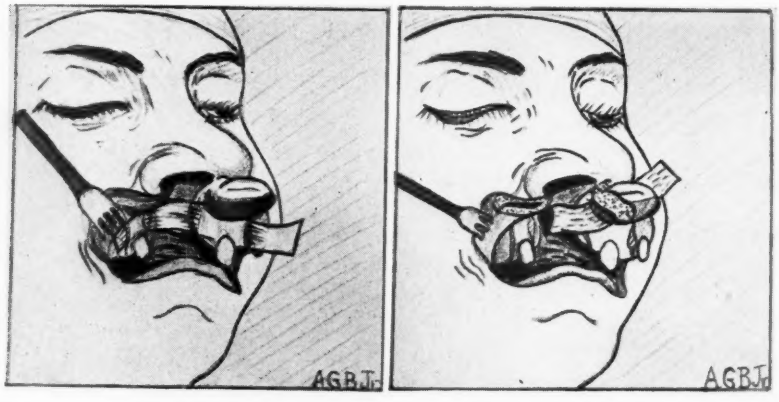
Gillies[1] has done more to forward the tubular pedicled graft than any one else. Maltz[2] has modified the Gillies tubular graft by turning the raw side, rather than the skin side, out. Dean,[3] calling his graft a dermigraft, first cuts away a Thiersch graft and then, beneath this, a split skin graft or full thickness graft. It has already been mentioned that after a split skin graft has been taken and the skin has regenerated, another split skin graft can be taken from the same area.

Earl C. Padgett of Kansas City uses a calibrated skin graft and has an instrument for cutting skin of any thickness or pattern from anywhere in the body.

Blair[4] of St. Louis, on December 11, 1928, before the Southern Surgical Association, showed the split skin graft and suction retractor; since then, he and Brown have given many illustrations of its use. Brown's paper[5] before the Southern Surgical Association in 1937

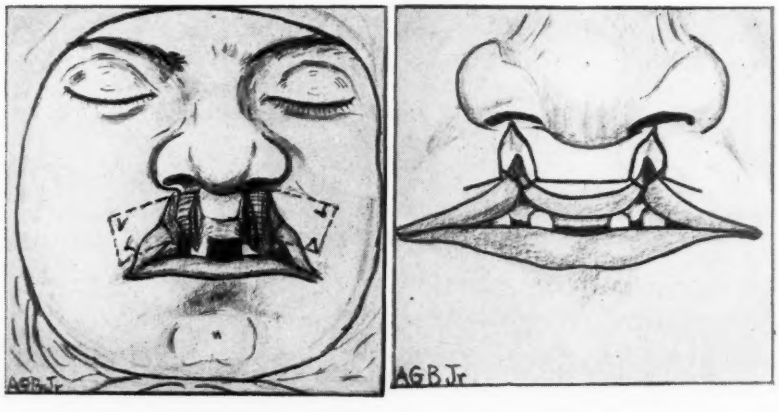
was a superlative account of grafting split skin and full thickness skin on the hand.

Blair has pointed out that the split skin graft has more of the



A B

FIG. 10. A, vomer-premaxilla sectioned at the neck or not sectioned. Strip of fascia inserted through opening in front under mucoperiosteum of premaxilla and out and under mucoperiosteum of premaxilla and alveolar process, where it is sutured. The fascial band is drawn upon tightly and attached, in similar fashion to the opposite alveolar process. B, second strip of fascia passed under philtrum between mucosa and muscularis and stitched out into the lips on both sides between the mucosa and muscularis, pulling lips together and relieving tension on the suture line. (From Brenizer, in *Ann. Surg.*, 107: 692, 1938.)

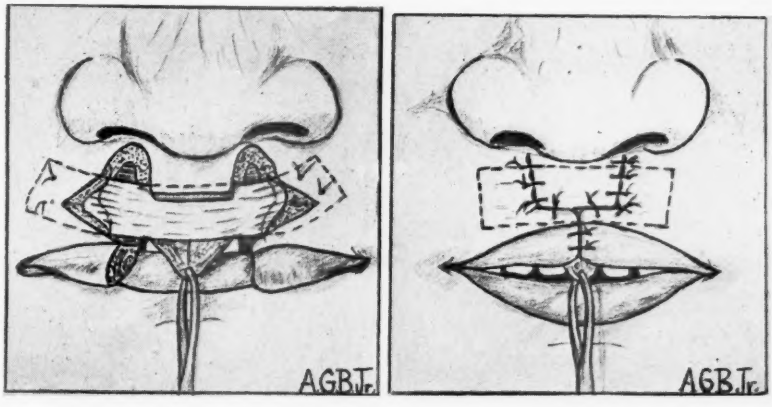


A B

FIG. 11. A, first operation performed upon double harelip, using fascial band. B, pattern of second operation where only the skin and muscularis are incised and the mucosa is left intact. (From Brenizer, in *Ann. Surg.*, 107: 692, 1938.)

good than the bad points of either the Ollier-Thiersch or the full thickness graft. With sufficient practice with Blair's suction retractor and knife one can cut a graft of almost any thickness and from 25 to 50 square inches in area.

The donor area must be free from pustules (for infection accounts for 90 per cent of the failures) and non-hair bearing. It is cleaned with ether, metaphen, and alcohol, and is covered with a thin layer of



A B

FIG. 12. A, band of fascia or ribbon catgut may or may not be used in second operation. The mucosa at the vermilion border is used to point up the lip. B, union of the pattern. When the band of fascia is employed, surface stitches may be avoided. Note the tip of mucosa crowning the vermilion border and pointing up the lip. (From Brenizer, in *Ann. Surg.*, 107: 692, 1938.)

vaseline so that the suction retractor will slide easily over the skin. As the skin is sucked up to a straight line and leveled against a countertraction, it is cut with a razor-sharp knife, making bold strokes out and back. One single graft, somewhat larger than the defect to be covered, is the goal desired.

The area to receive the graft must likewise be clean. It should be washed with soap and water, removing all scales and crusts, and is covered for a few days with warm saline solution. The granulations are curetted and cut away, down to the scar base, and the borders excised. All bleeding must be scrupulously stopped. If it is not completely stopped, a day's wait is in order. The graft should be sutured to the skin borders, loosely enough to avoid tension but taut enough to cover and fit the underlying structures. Rather than put stab wounds in the graft, it is advisable to insert small glass tubes between sutures at the skin border. The wound is dressed with several layers of xeroform gauze, a thicker saline gauze and a moist sea sponge cut to extend just to wound edge. The dressing is held with a pressure bandage; this pressure should be firm but not too hard. The dressing is changed about the sixth day, any serum evacuated, stitches removed, padding of gauze and sponge dispensed with and the wound covered with saline dressings for another week. Figure 3 is an

illustration of the ideal treatment of a fresh wound with good results. The back of the hand had been badly mangled in an automobile wreck and the distal phalangeal bones of the thumb were held

A B

FIG. 13. A, double harelip markedly projecting and deviating premaxilla. Diagram of fascial bands, section of vomerpremaxilla at neck. B, final result. (From Brenizer, in *Ann. Surg.*, 107: 692, 1938.)

by a flexor tendon. The hand was debrided, the tendons and even the nerves seen were united, and a free graft was done immediately. The result was excellent for function and fair for looks.

The area from which the skin is taken is covered with vaseline gauze and allowed to heal from the derma and hair follicles. When covered with epithelium this same area could be used repeatedly.

As far back as 1911 the experiments of Davis[6] are recorded, indicating most of the uses of free fascial flaps, except on body cavities and known infectious localities, such as the mouth and nose. In 1937,[12] I presented a report on the use of fascia in the repair of cleft palate and harelip, demonstrating two bony palates where fascia was used.

We have used fascia under bone grafts in skull defects,[7] to pad the cheeks, as bands to support the cheek and ectropic lower eyelid,[8] between mucous membrane and skin of the face and cheeks to support them, in harelip and cleft palate to support and relieve

tension on these structures and to have at least two bony palates,[8,12] to cover resected joint ends, and, in addition, as flaps and suture material in bone grafts[11] and in repairing the abdomen, particularly in herniae.

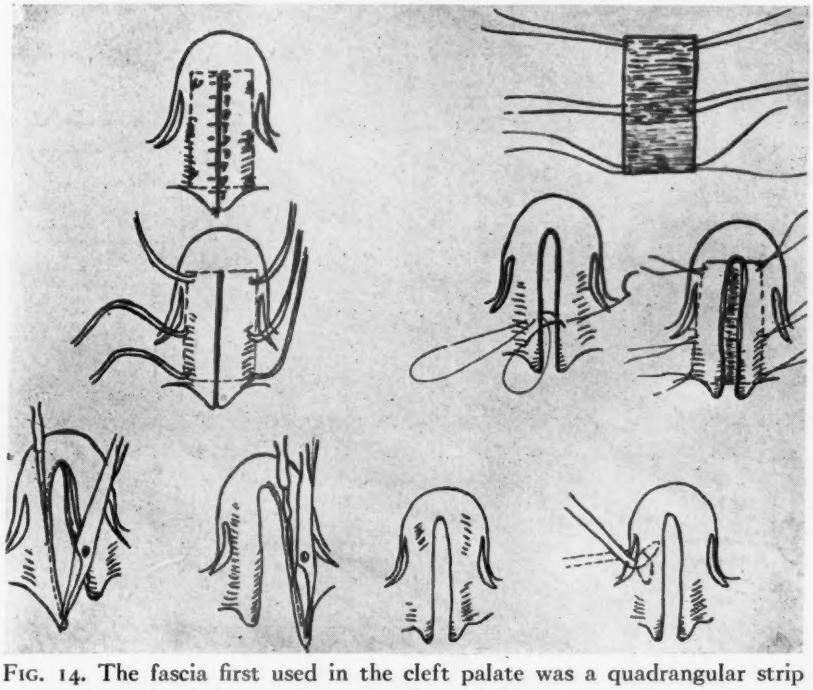
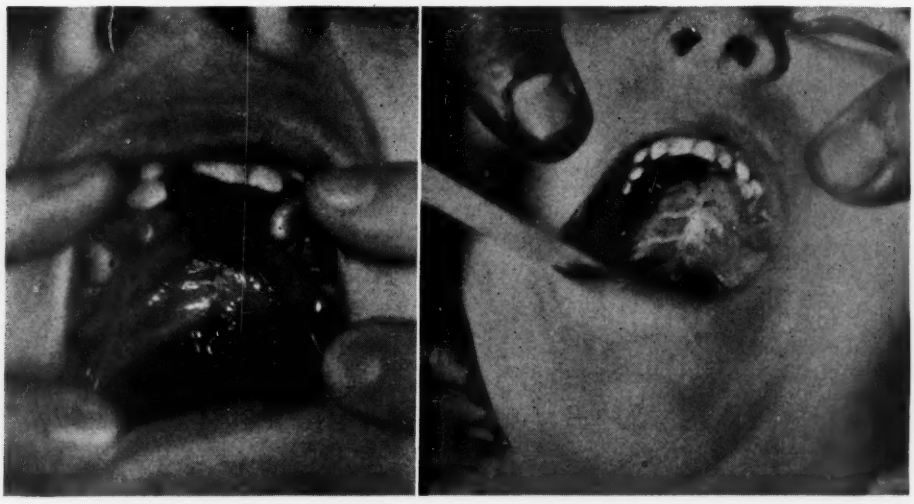


FIG. 14. The fascia first used in the cleft palate was a quadrangular strip placed in behind the mucoperiosteal flaps of the Langenbeck type of operation, or between the buccal and nasal mucoperiosteal flaps of the Victor Veau operation. (From Brenizer, in *Ann. Surg.*, 107: 692, 1938.)

In a paper[7] in 1916 I suggested that fascia be used to replace the dura. In a soldier, who was shot in the back of the head a few minutes before the Armistice was signed, the occiput and right parietal were badly broken and shattered. He lost some more bone and the scarred brain bulged through the opening. The brain was reduced by ventricular puncture and held back by a strip of fascia and then covered by three bone shells taken from the upper end of the tibia. The result was excellent. (Figs. 4 and 5.)

The boy shown in Figure 6 was badly burned over his right cheek, the structures being cooked and shrunken. He wore in his mouth a pad of cotton, which suggested to me the idea of making an incision along the lower border of the mandible and separating the skin from what was mostly scar and mucosa, thereafter filling the cheek with fascia and fat.

The girl in Figure 7, when a child, had an abscessed cervical gland opened by a doctor who, at the same time, cut the facial nerve. Her lower lid hung down in an ectropion; her whole face sagged. A



A B

FIG. 15. A, first case, operated on at the age of three months, now 18 years old, retaining the fascial strip and showing a bony hard palate. Periosteal cells conveyed across the cleft in the hard palate. B, second case with bony palate, following fascial implant. (From Brenizer, in *Ann. Surg.*, 107: 692, 1938.)

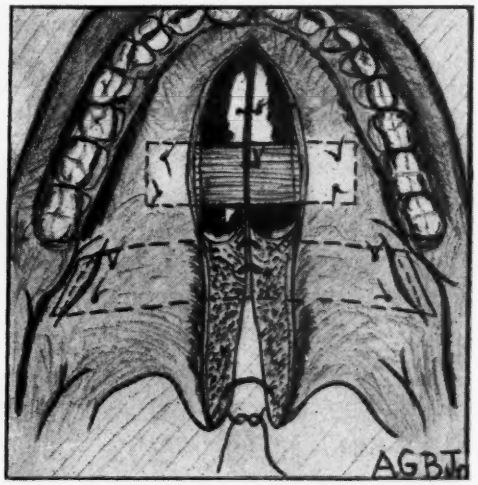
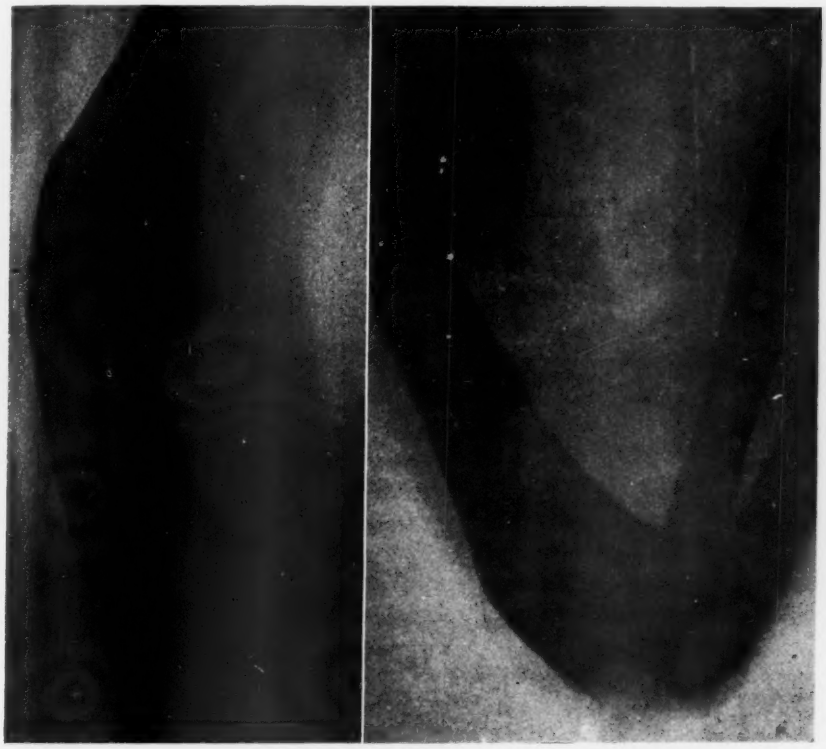


FIG. 16. Narrower strips of fascia or ribbon catgut, with a tie of fascia or ribbon catgut in the velum are now employed with good results. (From Brenizer, in *Ann. Surg.*, 107: 692, 1938.)

strip of fascia was passed between the skin and the musculature of the lower lid, suspending the two ends at the canthi. Three strips of

fascia were let down from an incision in the hairline, under the skin, to the ala, the mouth corner and lower border of mandible. This was a sort of a face-lifting scaffolding, which has remained fairly effective until this day.



A B

FIG. 17. A, resection of elbow with interposition of fascia. Elbow in extension. B, same case. Flexion of elbow. This same procedure has been used on hips, knees, etc.

A patient born with a cleft of the whole cheek, palate and maxilla up through the orbit (Fig. 8) had fascial bands placed between the mucosa and muscularis to relieve tension on the stitch line and reinforce the cheek. Following Dr. Blair's visit and sojourn with me during the World War, we used similar fascial bands to support the cheeks on my service at Base Hospital # 6, A.E.F.

Some of the cases shown in Figures 8 to 16 were shown before the Southern Surgical Association in December, 1937.[12] In these cases the fascia was inserted between the mucosa and muscularis in the lips and between the periosteum and bone in the palate and if Victor Veau's operation was done between the buccal and nasal flaps.

In four cases, comprising two ankylosed hips, an ankylosed elbow and a bunion, fascia was interposed between the resected and apposed bone ends. (Fig. 17.)

In a previous paper[11] I reported on the use of fascial ties instead of kangeroo tendon and chromic catgut.

A large pendulous panniculus adiposus with bulging abdominal

FIG. 18. Large watermelon slice taken from the skin and fat of the abdomen. Fascial planes plicated. Plication well aided by using strips of fascia taken from the planes. This case is a reminder of many uses of fascia for replacement, support, etc.

walls illustrates the type of case in which fascia is used in internal corsetry or in inguinal and incisional herniae. The panniculus shown in Figure 18 was so large that when the patient, a singer, reached a high note, an enormous load of skin and fat would suddenly shoot from under her corset. In these cases, before there is any tightening of the fascial planes, a large watermelon slice of skin and fat is removed. In one of these cases the operation was begun for me by a cow, who nicely horned up the whole panniculus, from the inguinal regions to the navel. A number of these patients have expressed their gratitude for the shrinking of the figure, if for nothing else.

CONCLUSION

The patient himself offers a handy and effective material in his skin and fascia, to relieve his own misery and embarrassment and to bring to the surgeon a remarkable mixture of abuse and praise.

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THE USE OF SMALL DEEP GRAFTS IN THE REPAIR OF SURFACE DEFECTS

JOHN STAIGE DAVIS, M.D.

BALTIMORE, MARYLAND

Introduction. The healing of lesions in any location due to the break in continuity of tissues, whatever may be the cause and however great or small the lesion may be, is the foundation on which all surgery is based.

The healing of denuded areas following destruction of surface tissue has always interested me a great deal, and in this connection I began to experiment nearly thirty years ago with a type of graft which I have called the "small deep graft." During this period, I have written several papers on the subject, and anyone interested in the story of the development of this graft and in the literature is referred to these articles.

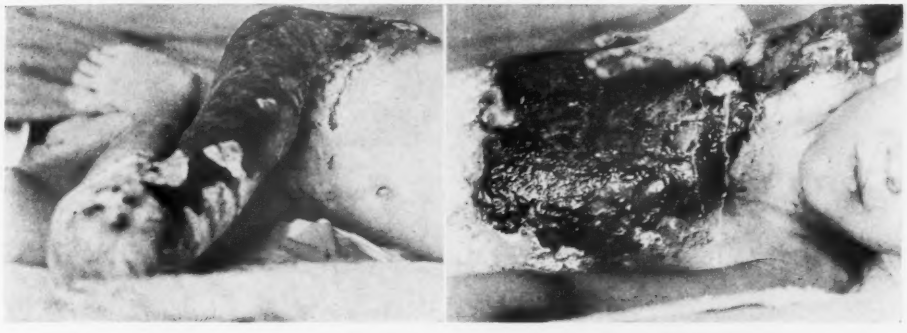
Those of us who have to deal with large surface losses due to burns, industrial injuries or traffic accidents are often confronted with the question of how best to hasten the healing. In a comparatively few cases immediate grafting must be considered, but in the large majority of cases it is necessary, for various reasons, to delay the use of grafts until a later period when there is more likelihood of successful results.

In this communication, attention will again be called to the value of very small grafts in hastening wound healing, particularly those grafts which are slightly larger and contain more of the full thickness of the skin than the very thin small grafts advocated by Reverdin.

Reverdin first described his graft in 1869 as a pure epidermic graft, but later said that the title "epidermic grafts" was not perfectly correct, "as the transplanted bit is composed of the whole epidermis and a very little of the dermis." In other words, it was the thinnest graft which he could cut.

The small deep graft differs from the Reverdin graft in that, although the margins are quite thin, the thickness gradually increases so that at the center, the graft usually includes the full thickness of the corium. These grafts differ in thickness from true Reverdin grafts practically as much as whole thickness grafts differ from true Ollier-Thiersch grafts and should not be confused with thin Reverdin grafts.

At one time Reverdin grafts were obtained by pinching up a superficial bit of skin with forceps and pinching it off with scissors. On account of this pinching method, the grafts were called pinch



A B

FIG. 1. Old unhealed burn in an 11 year old boy. Duration one year. A, note extent of involvement. Thigh flexed to more than right angle. Leg flexed on thigh. Fusion in groin. B, fusion of arm and forearm to chest wall, obliteration of axilla.

grafts. One frequently hears the term applied to small deep grafts, but this is incorrect, as small deep grafts cannot be properly cut by pinching off with forceps and scissors. Furthermore, Reverdin grafts, which are now seldom used, are no longer cut by this method on account of the unnecessary trauma to the tissues. It seems rational, therefore, to abandon the term pinch graft.

Nomenclature. The term epidermic graft is to be found in almost every article on skin grafting in which nomenclature or types of grafts are considered, but this term is inaccurate as there is actually no such thing as a true epidermic graft. There is no instrument as yet available which can cut pure epidermic grafts without some of the corium being included. As a matter of fact, a pure epidermic graft can be obtained in regions ordinarily used only by forming a blister, which raises the epidermis alone, and then by trimming this blister off and using it as a graft.

In a general way skin grafts may be grouped as thin and thick. In the thin group are those grafts which are made up of the epidermis and the tips of the papillae of the corium. True Reverdin grafts, 2 or 3 mm. in diameter, and true Ollier-Thiersch grafts (thin films of varying size) belong in this group; these are the thinnest grafts which can be cut. In the thick group are those grafts which are made up entirely or partly of the full thickness skin. Small deep grafts, whole thickness (Wolfe-Krause) grafts and sieve grafts belong to this group.

Other grafts very much used at the present time are obtained in the same way that Ollier-Thiersch grafts are cut, and in reality are

simply thick Ollier-Thiersch grafts. These are variously termed split grafts, intermediate grafts, razor grafts, mid-thickness grafts, etc., according to the taste of the author.

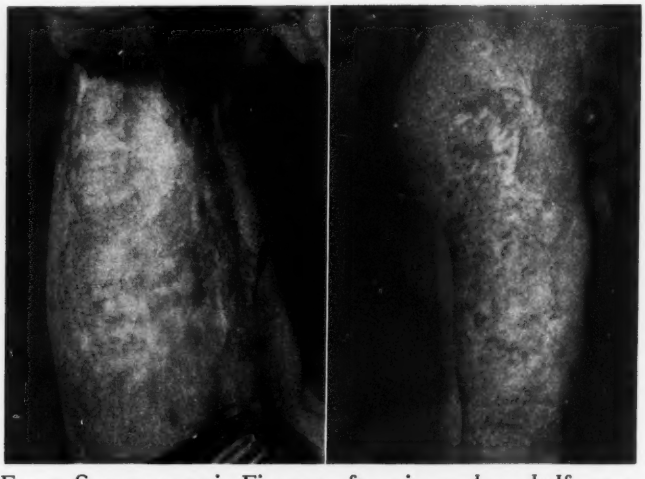


FIG. 2. Same case as in Figure 1 after nine and one-half years. The contractions were relieved by incisions and traction. The wounds were healed with small deep grafts. Note the condition of the chest wall and axilla. Slight recontraction in anterior axillary line. The leg and thigh can be fully extended and there is no evidence of recontraction. The size of these areas and the precarious condition of the patient precluded the use of any other type of graft. The appearance of the grafted areas compares favorably with that resulting from the larger types of graft.

Source of Small Deep Grafts. Auto or self grafts are almost uniformly successful when placed on a granulating surface which is in proper condition.

Iso, or homo, or same species grafts are occasionally permanently successful although it has been said that this is a biological impossibility. They will nearly always take on a suitable surface and will live and spread and stimulate growth from the edges, but usually in about three weeks, following a more or less severe anaphylactic reaction, they will melt away overnight. At one time, we used iso grafts quite frequently, but in recent years they have been rarely employed.

Zoo, or hetero, or animal grafts will frequently take at first, but are seldom, if ever, permanent.

Small deep grafts may be cut from any available portion of the skin, but where possible they should be taken from areas which are ordinarily covered by the clothing as the multiple small scars which are left after healing are more or less unsightly. We can almost

always find a usable area of normal skin, however extensive the destruction may be. The region from which the graft is taken has little if any effect on the result, but my preference is for the upper

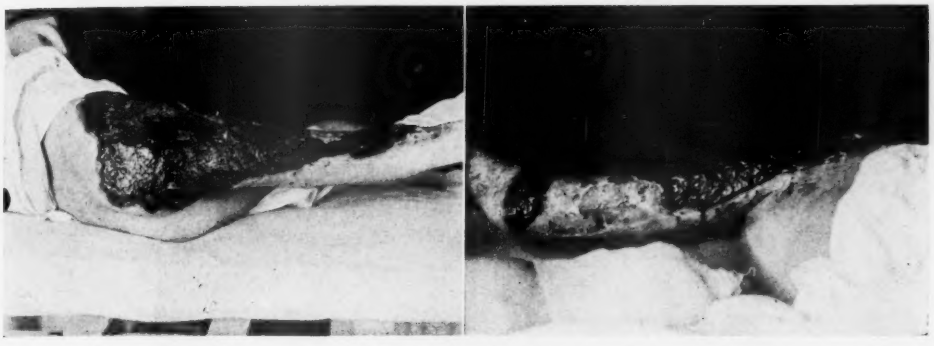


FIG. 3. Old unhealed burn in a 7½ year old girl. Duration thirteen months. Appearance of the granulating wound of thigh and knee. Note flexion due to scar contracture at knee and hip.

anterior surface of the thigh, if available, as the skin is not too thick and has about the right tension.

Surface on Which Grafts May Be Placed. Small deep grafts may be placed on fresh wounds; on surfaces from which the granulations have been entirely removed; and on surfaces from which the granulations have been partially removed by slicing off the undesired portions. In most instances, however, they are placed on undisturbed clean, flat, firm healthy granulations, as there is no pain in the process; no danger of stirring up infection; no loss of blood, which is an important point in patients already much depleted.

Preparing a Granulating Area for Grafting. Each surgeon has his own ideas as to when granulations are ready and how to prepare them. Suffice it to say that when the granulations are clean, firm, flat and rose pink in color, and the bacterial count is low or negative, the wound is ready to receive the grafts.

The question is frequently asked, "How do you get a granulating wound into this condition?" The procedure depends on whether the granulations are boggy and exuberant or whether they are scanty and sluggish. Some of the methods which have proved useful to me are as follows: When the granulations are boggy and exuberant, free application of silver nitrate, either in stick or as a saturated solution is often effective. Sulfate of copper in the crystal form or as a saturated solution is also useful. Slicing the granulations off with a scalpel or trimming them closely with curved scissors, followed by the application of silver nitrate or copper sulfate, is quicker and more positive. Thorough curetting of the granulations may in certain

instances be the method of choice. Continuous compresses of bismuth, or iodoform gauze, or plain gauze saturated in sterile glycerin may be helpful.

FIG. 4. Same case as in Figure 3 after twenty-one years. There is strong, flexible healing with no tendency to re-contracture. There has been no interference with the growth of the injured leg, as compared with the normal one. The grafted skin is freely movable over the underlying tissues. The appearance is good. The patient says that she has no discomfort whatever, that function is normal, and that she does not realize that anything was ever wrong with her leg and thigh.

Edematous and exuberant granulations may be flattened by evenly applied pressure. A sheet of rubber or rubber protective with small darts cut in it is placed over the granulations. Then sterile sea sponges or rubber sponges are applied and snug pressure is induced with bandages, elastoplast or adhesive plaster. Sometimes pressure produced by tightly applied adhesive strips or by 4 inch elastoplast bandages is sufficient to flatten the granulations.

Although the proper use of Dakin's solution by the Carrel method is rapidly being lost sight of, I still use this method with a great deal of satisfaction, and granulations which are exuberant and edematous will often in a few days shrink and become firm and healthy. Dakin's solution, used by the haphazard methods frequently seen today, is usually ineffective. Exposure for a short time for several days in succession to ultraviolet light may aid in the sterilization of granulating areas, and will also help in flattening out exuberant granulations.

When the granulations are sluggish, stimulating treatment is necessary. Painting the wound with 2 per cent nitrate of silver is

sometimes helpful. Compresses saturated with normal salt or boracic acid solution may be effective. Compresses saturated with sodium chloride solution 15 to 20 per cent or with glucose solution 20 to 40

A B

FIG. 5A AND B. Male, 42 years old, twenty-three years after grafting of an extensive deep burn of the leg and thigh with small deep grafts. The grafted area is soft and movable, and as stable as normal skin. There is no tendency to scar contracture although the flexor surface of the thigh, knee joint and leg was grafted. The contour of the popliteal space is normal in appearance. The healed area is loose and can be easily pinched up. The appearance is about as good as that which would have followed the grafting of such an extensive area with the larger types of graft. The small scars of the wounds from which the grafts were taken can be seen on the other leg and thigh.

FIG. 5C. Same case as in Figure 5A and B.

per cent will often start granulations on a sluggish base. Gridiron incisions through the scar tissue base may stimulate the growth of

granulations. If the scar base is very thick and the wound old and sluggish, it is sometimes necessary to excise the entire base down to normal tissue with as much of the margin as is necessary. The application of plain or iodoform gauze saturated with either undiluted balsam of Peru or in combination with castor oil 1:3 is frequently helpful. Immersion in a continuous tub is often useful in cleaning and stimulating granulations. Heliotherapy in the form of electric light baths and real or artificial sunlight in suitable amounts are valuable in treating all types of granulations and will often stimulate growth.

Granulations are sometimes stimulated and cleaned up by painting the entire wound with saturated solution of silver nitrate followed immediately by full strength tincture of iodine which forms silver iodide. Painting the granulations with gentian violet 5 per cent in water, or with dahlia 2 per cent in water, is useful in certain cases.

Preparation of the Area from Which the Grafts Are to Be Cut. After the area is shaved, a thorough scrubbing with green soap and water followed by ether and alcohol is the most satisfactory method of preparation for this area.

Preparation of Healthy Granulations to Receive Grafts. On the day preceeding the grafting, the wound should be carefully cleansed, and then dressed with a thick pad of plain gauze or iodoform gauze saturated with normal salt solution. This gauze pad is allowed to dry out, but immediately before operation, is thoroughly soaked with normal salt solution and is removed, care being taken not to cause bleeding. The skin around the granulating area is prepared by any method which has the surgeon's confidence. The wound is washed with ether followed by normal salt solution. A pad of dry gauze is placed over it and is pressed down firmly on the granulations. The dry gauze is peeled back from the granulating wound just before the grafts are applied, as the surface to be grafted should be dry, but not glazed, as is the case when the surface is left exposed to the air.

Anesthesia. General anesthesia is rarely used for cutting small deep grafts except in very nervous children or excitable adults. Ordinarily, they are cut under local anesthesia induced by nerve block or by infiltration, with ½ per cent novocaine containing four drops of adrenalin to the ounce. Moderate infiltration seems to have little if any detrimental effect on the healing of the grafts, but all things being equal, nerve blocking is preferable.

Operative Technique. Place the patient in a comfortable position on a bed or a well padded table. Approximate the area of skin required to supply the necessary grafts, and outline this area in the

shape of a square or rectangle with brilliant green 5 per cent in alcohol. This localizes roughly the area to be infiltrated. If one anticipates the excision of the area from which the small deep grafts are taken, in order to make a line scar instead of multiple small scars, then the outlined area should be in the form of an elongated ellipse, and the grafts taken from inside this outline.

After the desired anesthesia is induced, a bit of epidermis is picked up on the point of a shortened straight intestinal needle held in an artery clamp and is raised so that a little cone is formed. Sharp knives are essential for accurate graft cutting. By cutting through the tip of the cone with blade level we can obtain a Reverdin graft. When the base of the cone is cut through, the blade being slightly tilted downward until the center of the graft is reached and then turned upward and outward again, a small deep graft is obtained.

The grafts are preferably round or oval, between 4 and 5 mm. in diameter. They should not be larger. They are thickest in the center where the full depth of the skin is usually included and taper off toward the edges where they are quite thin. The subcutaneous fat can be seen shining through the central portion of the little wounds from which the grafts are taken. A thin rim of undisturbed epithelium should be left between the pits made in cutting the grafts.

The grafts when cut are dislodged from the needle on to a folded towel which has been wrung out in normal salt solution. This will remove any blood which may be on the raw surface. The assistant applying the grafts picks up each one on another needle, and, after peeling back the dry gauze pad from the granulations, places the grafts about 5 mm. from the wound edges and from each other, with the epithelial surface up.

After the grafts are in place it is essential that the thin edges be uncurled and spread out on the granulations and that in addition the thick portion of the graft be in close contact with the granulations at every point. This uncurling and close contacting is accomplished by firmly pressing directly downward on the grafts with a gauze pledget. After the grafts have been uncurled and pressed down on the granulations, any one of several methods of immobilization may be used. In one, which I prefer, the grafted area is covered with overlapping strips of rubber protective about 2.5 cm. wide in which v-shaped slits have been cut. These strips are long enough to extend out on the surrounding skin to which they are secured by a few drops of chloroform. Another method is to place over the grafted area strips of paraffined mesh secured to the skin by adhesive plaster, and over the mesh a single layer of xeroform gauze, 3 per cent.

Immobilizing can also be accomplished by stretching a single layer of wide mesh plain gauze tightly over the grafted area and securing the margins to the skin with adhesive plaster or collodion. Over the gauze a single layer of xeroform gauze is placed.

Further immobilization is obtained by placing over the protective or paraffined mesh or plain stretched gauze, a thin piece of sea sponge, cut to cover the grafted area. Over this a thicker and larger sea sponge is placed, which projects beyond the grafted surface, the whole being secured under even pressure by means of adhesive plaster and a bandage.

Another method which is extensively used after the grafts are in place, is to expose them to the air from six to twelve hours in order to set them. This is done either with or without immobilization by means of paraffined mesh or plain gauze. It should be noted that the same effect can be obtained by exposing the grafts to a hot air douche for a few minutes. I prefer the closed method as it is easier on the patient and gives the best immediate and ultimate results.

Dressing of the Donor Area. Silver foil is the most satisfactory dressing for the area from which small deep grafts have been cut. Several layers of foil are applied and over this the porous paper which separates the leaves. Then a single thickness of gauze impregnated with 3 per cent xeroform ointment, and finally a flat gauze dressing secured with adhesive plaster and a bandage. This dressing is left undisturbed for about two weeks, and when it is removed the little wounds will usually be healed.

Postoperative Treatment. Immobilization of the part and confinement to bed for a longer or shorter period, depending on the size and situation of the grafted area, are essential when dealing with large wounds. In smaller wounds in suitable situations ambulatory treatment may be used. When the grafts are placed on a granulating surface the first dressing should be done after forty-eight hours; when on a fresh wound, the dressing may be delayed for a week or longer. Frequently, the grafts placed on a granulating surface and dressed with rubber protective strips will be found bathed in a creamy secretion. The protective should be removed, and this secretion should be gently mopped up or irrigated with normal salt solution. Then protective strips and sea sponge are again applied and secured with even pressure. If paraffin mesh is used, it is left in place and removed at the second dressing. Within forty-eight hours after grafting, those grafts which will live become dusky pink with a deep blotchy area in the center. A narrow halo of newly formed epithelium can often be seen around each graft. Those grafts which do not take

are pearly white in color and will come away with the dressings in the course of a few days.

It is unnecessary to reapply the sea sponge pressure after the first dressing, although a snug dressing is desirable. When the grafts are growing satisfactorily and spreading, some bland ointment on old linen is useful. When the growth of the epithelium from the wound and graft margins seems sluggish, 8 per cent scarlet red ointment will often cause stimulation of the growth. Compresses saturated with Dakin's solution may be used to flatten them without harm to the grafts after the fifth day. As soon as the newly formed epithelium from the grafts and the wound edges has fused, stearate of zinc powder and exposure to the air are helpful. The grafted area should be protected from injury for several weeks. About three weeks after healing has taken place, gentle massage should be started and should be continued until the grafted area slides easily over the underlying tissues. Desquamation of the healed grafted area usually occurs and continues for several months. This can be controlled by the application of cold cream or some other bland ointment.

On an extensive wound, it is seldom that we find all the granulations in the same condition at the same time. If a small portion of the wound is ready to receive grafts, then the grafts should be placed about 5 mm. apart over this area. If a large area is ready for grafting, small deep grafts may be placed about 5 mm. apart over the whole area or may be scattered over it, and then in a few days more grafts may be put in the spaces between. This is continued until the grafts are approximately 5 mm. apart over the whole wound. Other portions of the wound should be grafted as they come into suitable condition, always aiming to have the grafts in the end not much more than about 5 mm. apart. The reason for this is that when small deep grafts are placed at greater intervals than 5 mm. apart, the granulations between them may become exuberant before the epithelium from the margins of the grafts can fuse and cover them, and thus control the growth. Grafts may in this way be overwhelmed by granulations and in some instances are completely buried and eventually absorbed.

From each small deep graft, 4 or 5 mm. in diameter, epithelium will spread over an area from 2 to 2.5 cm. in diameter if the grafts are placed with considerable intervals between them. Although good results are often obtained under these conditions, the healing will be more stable if they are planted with spaces of about 5 mm. There is usually stimulation of epithelium from the wound margins and from

the margins of the grafts previously applied following each successive application of these grafts.

There is no limit to the number of small deep grafts which can be cut at a sitting. Naturally, it is a much more irksome procedure to the operator to cut and apply several hundred of these grafts at one time than it is to cut and apply a large Ollier-Thiersch or whole thickness graft.

Preservation of Grafts. The idea is prevalent that skin grafts of all kinds must be applied either immediately or within a comparatively short time after cutting. Years ago I became interested in the preservation of skin grafts and have experimented with the refrigeration of various types. I soon became convinced that there was no hurry in applying skin grafts and that they could be preserved quite simply. If the grafts were to be used within twenty-four hours, wrapping them in sterile dressings moistened with normal salt solution to keep them from drying out, and storing in the icebox was sufficient. If longer periods were desired, the grafts were stored in jars of sterile yellow vaseline or sterile albolene in the coil compartment of a mechanical refrigerator.

For practical purposes, iso or zoo grafts can be eliminated from the problem of refrigeration as in the majority of cases, even if immediately transplanted, they do not cause permanent healing. Ordinarily, if grafts are cut in excess of the number immediately required, they are preserved and can be used later. Sometimes more grafts than are needed are deliberately cut and preserved. Now and then, an operative wound prepared for grafting will continue oozing in spite of all efforts to check it, to such an extent that grafts which have been cut cannot be applied immediately with any assurance of success. In these cases, the preservation of the grafts until bleeding ceases is important and when the surface is dry, either later in the day or on the day following, the grafts can be applied.

In large granulating wounds, it is seldom that the entire surface is ready for grafting at the same time. In these instances, the area which is ready is grafted, and surplus grafts cut at the same time are refrigerated and can be used at any time another portion of the surface becomes ready to receive them without any more discomfort to the patient than that of an ordinary dressing. As a matter of fact, it is seldom necessary to preserve grafts for actual use for longer than three or four weeks, as after that lapse of time the patient is usually healed or is in suitable condition to permit the cutting of fresh grafts.

The grafts, when removed from the vaseline or albolene, are as pink as when they are put in and look quite fresh. They are either

wiped gently with sterile gauze to remove the vaseline or are washed with ether before being placed on the granulations. It was noted that while the refrigerated grafts would take, and the blood supply become established, that it was fully a week and sometimes longer after transplantation before any new growth of epithelium was observed from the graft margins, and that this growth seemed slower than from immediate grafts of similar type. Microscopically, no definite change was observed in the cells of grafts refrigerated as above described, even after several months. Immediate autografts are always to be preferred, but I also feel that refrigerated autografts have a distinct field of usefulness, and that excess material should be preserved in suitable cases and used as required. Refrigerated small deep grafts are permanently successful, and we have successfully transplanted them after five weeks.

Frequently, the treatment of large surface losses of tissue is turned over to inexperienced interns, as such surgery is considered unworthy of the personal attention of the upper house staff. As a matter of fact, however, the successful treatment of large surface lesions is in many instances a very much more difficult bit of surgery, and harder to handle than many of the so-called major surgical procedures. In certain hospitals the first operation assigned to interns is that of treating burned areas with small deep grafts, or a reasonable facsimile.

The grafts are in many instances improperly cut as to depth and size and distance apart; are cut from areas such as the front and back of the leg, arms, breasts, over the sternum, and from other exposed positions; are placed on areas where other types of grafts should be used; are frequently put on granulating areas which are not properly prepared to receive them; and are improperly spaced, dressed and treated. The procedure is simple, but frequently I have noted that the surgeons who give the instructions to the interns have themselves a very indefinite idea of what a small deep graft is and of the essential details necessary for success. In consequence, the grafting is done quite inefficiently, and the results are in proportion.

We frequently see grafts cut which are from 1 to 1½ cm. or more in diameter and which are erroneously called small deep grafts. These grafts are unsatisfactory for several reasons: The result is more unsightly; not so much epithelial proliferation is possible from the margin of a single larger graft as from several smaller grafts whose total area is the same; where available skin is scanty, more is wasted than when small deep grafts of the proper size are cut and properly spaced; and the resulting scars are more objectionable.

In surgery, as in every other type of work, there is a great deal of difference in the way two men will carry out the same procedure.

Poor results, both immediate and subsequent, are often due to the lack of care in the preparation of the surface to be grafted. One has only to look about in any hospital where small deep grafts are used, to see that this is true, as some men, frequently have poor results, while others, who are meticulous in their pregrafting preparation, are almost uniformly successful.

Often, however, we are forced by circumstances to place small deep grafts on granulations which are in unsuitable condition for grafting, and it is surprising how frequently they will take on these surfaces where no other type of graft could survive, except possibly the thin Reverdin graft. Care should be taken to avoid the transfer of infection from the granulating wound to the area from which the grafts are cut.

It should be an unbreakable rule that when any type of graft is contemplated, the area from which the graft is cut should be selected with the idea of conservation of graft resources for subsequent use, if it should ever be necessary. Of course, other grafts cannot be taken from exactly the same area from which small deep grafts have been cut, but this is the case when a graft of any type has been previously taken. It is regrettable that in many instances, large areas of skin are completely eliminated for future graft supply by the thoughtless or unskilled operator, using, for instance, the whole anterior surface of a thigh to supply fifteen or twenty small grafts. This cannot be charged against the method, but is due to the stupidity of the operator.

As a matter of fact, one advantage in using the small deep graft, besides starting islands of skin over a large denuded area, is that grafts are taken from a comparatively small skin area, and if they are properly cut with proper intervals between, a greater raw area can be healed from a smaller skin source than by any other method. This may be verified by giving actual measurements in several recent cases. An area $7\frac{1}{2} \times 6$ cm. yielded 108 small deep grafts; another $6\frac{1}{2} \times 5$ cm. yielded ninety-one grafts; another 6×6 cm. yielded 100 small deep grafts. Now these grafts, which should be 4 to 5 mm. in diameter, may be scattered widely over a large granulating area. When, however, we take the 6×6 cm. area from which 100 grafts were obtained and place these grafts about 5 mm. apart on a granulating surface, which is as close together as grafts of this type should be placed, they will cause stable healing on an area a little over 10 cm. square. On the other hand, if we cover an

area 10 cm. square with a thin or thick Ollier-Thiersch graft, it would require the denudation of a normal skin area larger than 10 cm. square. If this 10 × 10 cm. area was to be covered with a whole thickness graft, it would require the excision of a graft of the same size, 10 cm. × 10 cm., to accomplish it.

An area 10 cm. × 10 cm. is comparatively small when we consider the large surfaces which are often destroyed in extensive burns, industrial and accidental injuries, and operative excisions. The denudation of an additional area of 10 cm. square, or even considerably larger, in obtaining a thick or thin Ollier-Thiersch graft or whole thickness graft is of little importance, but when we have areas many times 10 cm. square to cover with these grafts, the situation changes, as the larger the wound surface to be covered, the larger the area must be from which these grafts are taken, and in consequence, the greater the additional denudation of skin surface and the greater the operative procedure. The denudation of this extra amount of skin surface, in addition to the original large wound, is often a serious added burden to the already depleted patient.

Some surgeons use Ollier-Thiersch grafts, either thick or thin, for almost every wound requiring grafting, while others use whole thickness grafts, and still others use small deep grafts. The most rational procedure is to use the type necessary for the needs of each individual case and supplement with any other type desired. For instance, when we have a large granulating surface, it is frequently impossible on account of the condition of the patient or the lack of available skin surface, to cover it completely with either thin or thick Ollier-Thiersch grafts or whole thickness grafts, even if these types were to be preferred. In such a case, small deep grafts offer the solution of the problem as they may be applied here and there over the surface to start islands of skin, then in a few days other grafts are placed between those already applied and so on until the new epithelium covers the area.

The results as far as appearance is concerned are less satisfactory than those of successful large, thin or thick Ollier-Thiersch grafts or whole thickness grafts, which completely cover the defect. The healed area is spotted with small grafts whose centers are the full thickness of the skin. However, in the majority of instances, small deep grafts are used to induce rapid healing in areas which are ordinarily covered by clothing, and appearance is not particularly important. Where the proper technique is carried out, the permanence and durability of the healing is much more stable than

following thin grafts of any type, and as stable as the results of whole thickness grafts.

On account of the dotted appearance of a surface successfully grafted with small deep grafts, it is inadvisable to use them on the face and other exposed positions except to hasten healing in special instances where subsequent removal is contemplated. Sometimes a brownish pigmentation may form in the grafted area, but this also occurs when other types of grafts are used.

It must be borne in mind, however, that the appearance of a wound healed with strips or patches of whole thickness grafts or thin or thick Ollier-Thiersch grafts is also blotchy and is often more unsightly than a wound healed by small deep grafts. There is somewhat more shrinkage in the size of the original wound after healing with small deep grafts than after successful thick Ollier-Thiersch and whole thickness grafts.

The difference in the stability and character of the healing obtained after grafting with thin Reverdin grafts and with small deep grafts is almost as marked as that which is found between the results of thin Ollier-Thiersch grafts and whole thickness grafts. Wherever a small deep graft has taken, there is a permanent patch of the full thickness of the skin with all of its components, and these little patches of thick normal skin give stability to the healing.

It has been suggested that the healing of the little wounds left by cutting the grafts may be expedited by making oval grafts and suturing each wound. This is hardly necessary as the healing is usually prompt and the appearance of the scars of a sutured group of oval pits is little better than when suturing is not done.

The excision of the entire area from which small deep grafts are cut, with closure of the defect in a line, was advocated many years ago and abandoned, but has recently been recommended again. This necessitates a much more extensive surgical operation, and is really the same procedure as removing a whole thickness graft, which on a depleted patient is inadvisable. However, if the area from which small deep grafts are taken is to be excised, then it is unnecessary to leave a rim of epidermis between the pits made in cutting the grafts, and the grafts can be cut closer together.

Sometimes the scars from which small deep grafts are obtained thicken and become keloidal in character. This is an undesirable complication, and we do not know when it will occur or how to avoid it. Keloid also may develop in the scars left by the removal of thin or thick Ollier-Thiersch grafts and also in the sutured wounds from which whole thickness grafts are obtained. In other words, keloidal

scar tissue may develop in any scar from which any type of graft is obtained.

Occasionally in patients with a keloidal tendency, there may be a thickening of the scar between the grafts even if they have been placed quite close together. However, this thickening is more frequently seen when the grafts have been placed with intervals greater than 5 mm.

If small deep grafts are placed closer than 5 mm. apart, there is unnecessary waste of skin. The healed wound then has a cobblestone appearance, as the grafts do not tend to flatten out.

The objection has been raised that scar contractions may occur in areas healed with small deep grafts, but these can ordinarily be relaxed in due time without difficulty, when the scar has matured, and the patient is in proper condition. As a matter of fact, there is no type of free skin graft in which, after healing has taken place, scar contracture does not sometimes occur, either in the grafted area itself, or along the margins. This contraction is especially liable to occur on the neck, in the axilla or groin and around joints.

SUMMARY

It has been said that the results obtained by the use of small deep grafts are never satisfactory; that small deep grafts, often incorrectly called pinch grafts, should never be the method of choice; that by the use of these grafts the donor site is made useless as the source of other grafts, and that the method is a surgical error.

My experience has been that if small deep grafts are properly cut and are *really* small deep grafts; if they are used in the proper situation on a surface which is suitable for them; if they are properly spaced; if they are properly dressed; if the after-care is as it should be—the healing will be stable, strong and permanent, and there is no type of graft which gives more uniformly satisfactory results. Furthermore, small deep grafts will in many instances take on surfaces on which no larger graft could take.

If the best results are to be obtained with small deep grafts, several points must be observed. The granulating surface on which the grafts are placed should be healthy, clean, flat, firm and rose pink in color. The grafts should be cut without unnecessary trauma, should include the full thickness of the skin at its center and should be no larger than 5 mm. in diameter. In cutting, a narrow rim of undisturbed epidermis should be left between the little pits, and in this way a large number of grafts can be obtained from a very small area of skin. In fact, a greater raw area can be healed from a smaller

skin source than by any other method. The grafts should preferably be placed on the granulations with a space of about 5 mm. between them, although frequently excellent results are obtained when the spaces are greater. They should be pressed down firmly so that the thin edges will uncurl and so that every portion of the graft will be in close contact with the granulating surface. The grafts should be immobilized until the new blood supply is assured, and this is best accomplished by the closed method of dressing.

My own experience and that of many other surgeons during nearly thirty years has convinced me that the method is that of choice in a great many instances, and I feel that those who have not had good results, either do not know how to use this type of graft or do not take the trouble to use it properly.

In my own work I use small deep grafts constantly, with the greatest satisfaction, and find the method indispensable when dealing with large losses of surface tissue and in solving some of the complicated problems of wound healing.

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DISCUSSION OF PAPERS OF DR. BRENIZER AND DR. DAVIS

FENWICK BEEKMAN (New York City): We have used the small, full thickness pinch graft extensively at Bellevue Hospital in the Children's Surgical Service. There we have had a large number of burns, and also a great many cases of avulsion of the skin from the limbs. In all of these, we have used the small full thickness skin graft.

A point to be stressed is the preparation of the area to be grafted. In fresh burns, the grafting should be done just as soon as the eschar of the burn separates from the surface. We find that after this, the use of a wet dressing for twenty-four hours is sufficient, and then the part can be grafted.

In avulsion of the skin, the grafts can be placed as soon as the infection is cleared up. As Dr. Davis has said, the grafts can be used in some areas of the wound before others; the areas in which pockets of infection have been cleared up are ready first.

We so often see neglected burns, burns in which no grafting has been done and in which the epithelium has covered part of the limb but left ulcers. In these cases it is very important that the granulating area be entirely excised. If the excision is not made, there is not sufficient blood supply in the area and the grafts will surely fail.

My experience with isografts has been exactly the same as Dr. Davis', and for a great many years we have never attempted their use.

I think the work of Leo Loeb, done some years ago, is very interesting. He proved then that blood grouping and similar tests were useless, that isografts even from parents and brothers were useless, but that in *like twins*, isografting could be done. Identical twins have similar body reactions.

DONALD M. GLOVER (Cleveland): I was very much interested in Dr. Brenizer's cases of harelip and cleft palate and I would like to ask him concerning the fate of the fascia grafts used. It has been my experience that fascia grafts do not tolerate infection very well and, of course, in the oral cavity it is very difficult to avoid a certain amount of infection.

In regard to Dr. Davis' paper and illustrations showing the excellent results obtained with small deep grafts, I would like to emphasize further a fact which he brought out. It has been embarrassing to all of us to note the scarring of the donor areas. If these areas are not carefully selected or are scattered about the body, an undesirable type of skin remains permanently. All of us have, I think, had the unfortunate experience of having patients come in later life for plastic work upon the face after they have had numerous small full thickness grafts removed from various parts of the body in childhood. At the time we need to have good skin for full thickness grafts it is almost impossible to find an area of clear skin anywhere on the body. Some of us prefer to use the split thickness graft in areas such as Dr. Davis has described. It seems advisable to cover very extensive wounds completely with split thickness grafts (or if the entire area cannot be entirely covered at one sitting, one portion of the denuded area is completely covered, the next area at a subsequent grafting operation, and so on) because granulating areas are not left between grafts as when small deep grafts are used. A patient continues to lose weight and develop secondary anemia as long as sizable granulating areas persist.

In regard to isografts, we have for several years been doing experimental skin grafts in puppies and have found that in young litter-mate puppies we can get very satisfactory cross graft takes. However, beyond the age of about six months we have not been so successful. This is just a preliminary statement that may in the future offer some possibilities.

JOHN A. CALDWELL (Cincinnati): Our experience with the full thickness graft has abundantly corroborated all the claims made by Dr. Davis. It is by all odds the most useful way to restore denuded areas. We have also had absolutely identical experience with the isografts.

A method that we use in the treatment of the donor area is a distinct advance where the area is not too large, as for instance, an area in the thigh. Instead of taking small islands from a wide area, we will take them from a strip, possibly an inch wide, down the front of the thigh and have them so close together that the entire skin area from that strip will be denuded, and be excised and drawn together. A straight line incision results which heals by first intention.

ADDISON G. BRENIZER (closing): Dr. Glover asked about the fate of fascial grafts exposed to infectious cavities, as in the mouth or the nose. On the advice of Dr. Blair during the war, we used strips first of all to help hold the mucous membranes together in gunshot wounds about the face. Some persisted, and some did not.

I mentioned that in using a strip of fascia to take the tension off the stitch line in cleft palate, we had two bony palates left over. Grittiness of the palate and an inability to stick a sharp instrument through the bony part meant bone. Some palates became a little gritty anyhow. I believe, although I did not see the fascia again, that it persisted in spite of exposure to the nasal mucous membrane.

In several cases where the Victor Veau operation was used, the fascia was never seen again and served the purpose of taking the tension off the stitch line. Even ribbon catgut will do that. In some of these cases, we have, after a week or ten days, seen some part of the fascia again; in other cases we have not. Where the fascia was imbedded in the lip, it was not seen again. An objection to its use in the lip is that it produces unnecessary thickness, but this later disappears. We never see that fascia again. In some cases it remains; in others it may act as a scaffold and become absorbed like any foreign material. It serves the purpose of keeping the tension off the stitch line—and that is our requirement.

The first operation on cleft palate and harelip is the best opportunity for permanent repair, because never again is operation quite so easy. The disappointment of the parents if one fails is a further impedement to later attempts.

I have seen a doctor whose daughter was operated on by this method a number of years ago. She had been taken around the country and it was said that her palate could not be closed. She was advised to wear a diaphragm. Fascia was used, however, and although the midline did not quite meet, the fascia persisted until the midline did join. She now has rather a good palate, and they say that she actually sings well.

HIGH TENSION ELECTRIC BURNS*

CHARLES REID EDWARDS, M.D. AND HARRY C. BOWIE, M.D.

BALTIMORE, MARYLAND

I WISH to present this subject entirely from the viewpoint of the clinical surgeon. While much creditable work has been done in the laboratory, conditions prevailing where the workman is exposed to high tension wires or equipment cannot be duplicated there. A combination of circumstances, such as temperature, humidity, dryness or moisture of the skin of the workman, the areas of the body making contact, the size and shape of the electrodes, whatever they may be, duration of contact, and finally voltage and amperage, is difficult to reproduce.

Electropathology has been so well considered by Jaffe that it needs no elaboration. It is well known that electric current kills tissue, and that there is quite a difference in the way in which various tissues react to the passage of electric currents. Bone offers the maximum and skin the next greatest resistance to electric current, and blood is known to be the best conductor of electric current in the body. It naturally follows that the widest destruction of tissue is observed where resistance is greatest. This is of considerable importance and its application is seen in the location and type of burns encountered.

The classification of burns, as usually understood and accepted, really does not hold here. In destruction of tissue due to electric current heat is generated within the tissues, and destruction will follow wherever the current goes, provided it is applied long enough. In the ordinary burn heat is brought to the tissues from without. In high tension burns desiccation and charring occur immediately, beginning at the points of contact and extending along the path pursued by the current. The tissue is so completely devitalized and mummified or charred that there is no absorption from it, and consequently no toxemia. The ordinary first, second, and third degree burns seen in association with electric burns are usually due to the ignition of clothing or some inflammable gas or dust, and, therefore, are not true electric burns. I propose, accordingly, that we discard the old classification when dealing with burns due to electricity, and speak of them only as "electric burns." They are usually the result of a voltage somewhere between 1000 and 4500. Low

* From the Surgical Service, University of Maryland School of Medicine.

voltage, such as lights our homes, the usual 110 or 120 volt house current is seldom responsible for burns, but is frequently responsible for sudden death. Most of the severe cases here considered have been

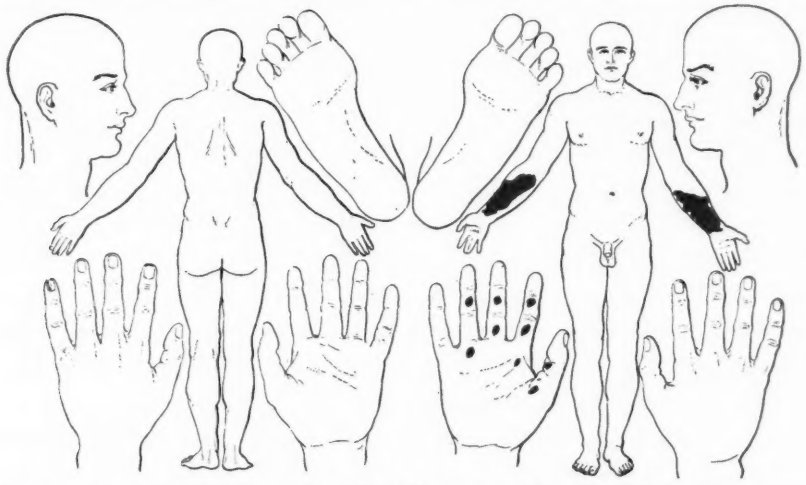

FIG. 1. C. B. Admitted immediatedly following accident in which contact was made with right hand and flexor surface of both forearms. Voltage was 500. The charring was so superficial that in two days it was possible to discharge the patient from the hospital. His recovery was complete.

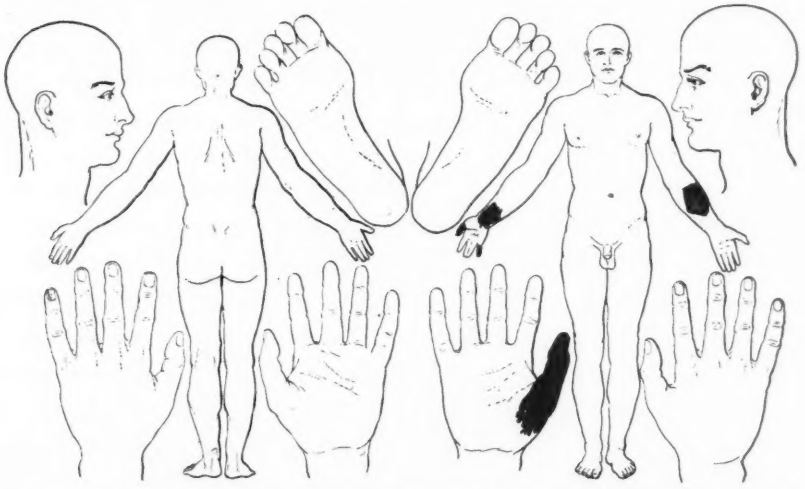

FIG. 2. C. M. Admitted soon after accident in which he made contact at several points involving right hand and wrist and left forearm. The voltage was 2,300. All injured areas were ischemic and soon became mummified, permitting a debridement of burned flat areas and requiring an amputation of the right thumb. The right fifth finger was entirely rigid due to damage to flexor tendons. It was painful and useless, therefore was amputated. A plastic operation permitted the use of the first metacarpal as a thumb.

exposed to less than 4500 volts. Some who were exposed to the higher voltage, 25,000 to 30,000, suffered severe local burns, and one, or

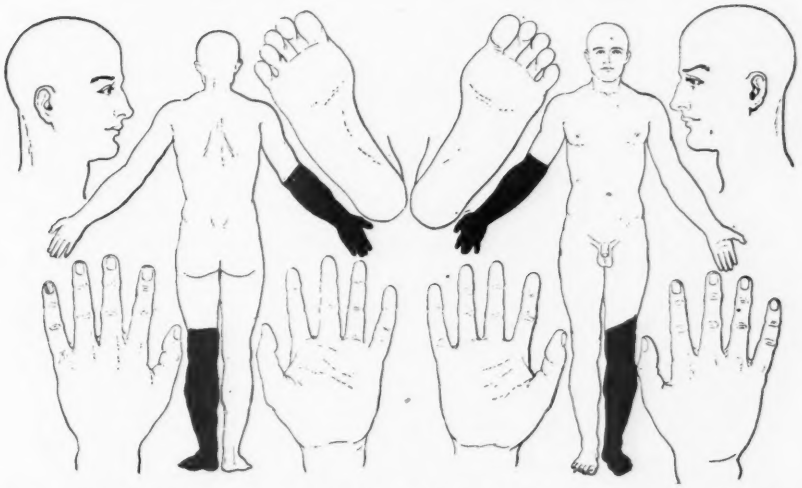

FIG. 3. M. H. Admitted one-half hour after injury, sustained by contacting right hand and left foot against a 4,000 volt line and pole. Contact maintained for one and one-half minutes. There was charring of foot and hand with ischemia and discoloration extending far up each limb. Complete mummification of affected limbs followed. Secondary hemorrhage at line of demarcation, right arm, necessitated a guillotine amputation at mid-arm on third day after admission, and anaerobic gangrene developing at line of demarcation, left thigh, required guillotine amputation of mid-thigh on seventh day. Complete recovery except for loss of limbs.

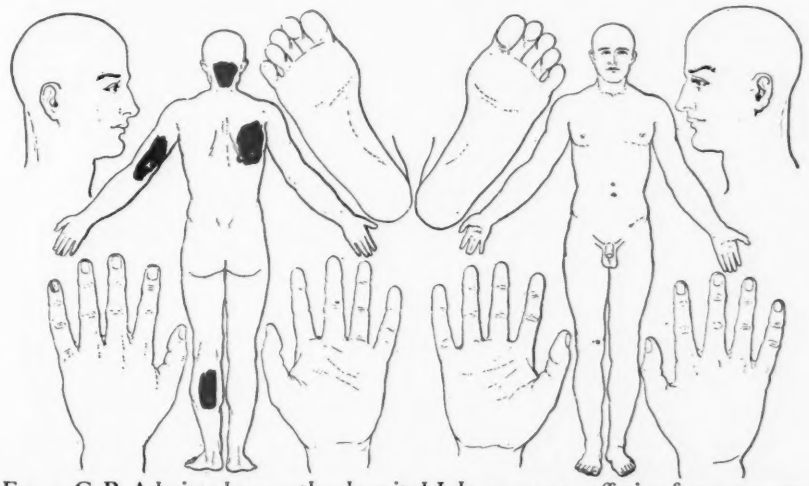

FIG. 4. C. B. Admitted to another hospital July 13, 1922, suffering from a severe burn on back of head, neck, back, left arm and left leg. He had fallen over a high tension wire. He was admitted to the University Hospital August 22, 1922. The wound on the head was badly infected. The outer table of the occiput, an area of 5 by 6 cm., had sequestrated and was removed. The wound was then grafted. The other wounds had healed by granulation. Patient recovered completely, and although badly scarred, he has been at work continuously.

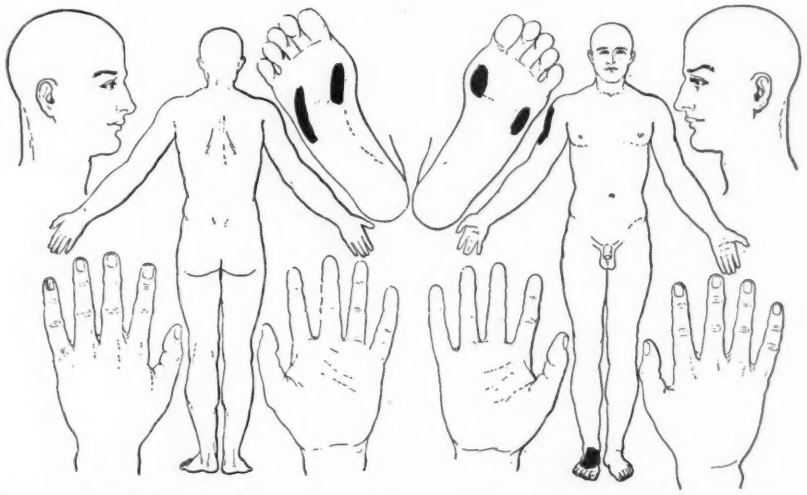

FIG. 5. H. C. While working 10 feet above the floor, contacted wires in unknown manner with right deltoid region and feet. He suffered electric burns of right arm, dorsal surface of right foot, and two areas on the bottom of each foot. The tendons on the dorsal surface of the right foot were exposed when the coagulum was removed twelve days after admission. Superficial areas of necrotic skin were removed from the bottom of the feet, and six weeks after admission skin grafts were applied to the dorsal surface of the right foot. He was discharged about eleven weeks after injury, recovery being complete.

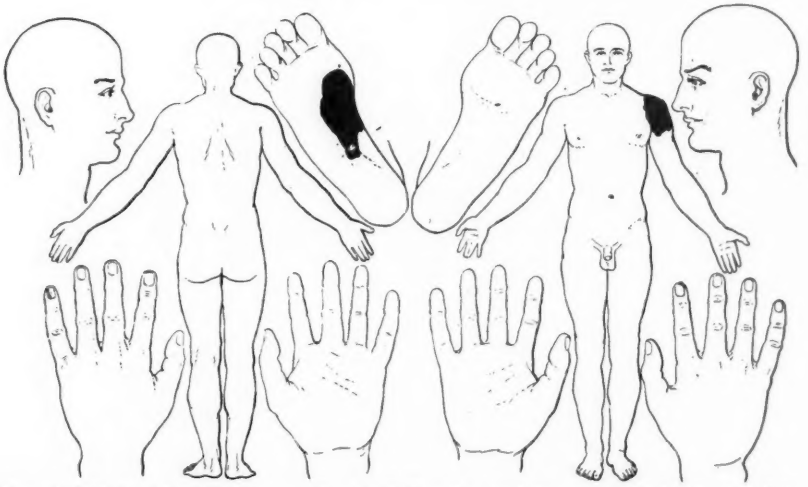

FIG. 6. W. A. Admitted immediately following accident in which left shoulder and right foot were in a short contact with a 13,000 volt wire. Patient dropped to the pavement and suffered an intertrochanteric fracture of the left femur. The burns were deep. The flexor longus hallucis tendon was exposed for 1 inch in the wound on the right foot. The wounds were packed with gauze saturated with azochloramid. Complete recovery followed.

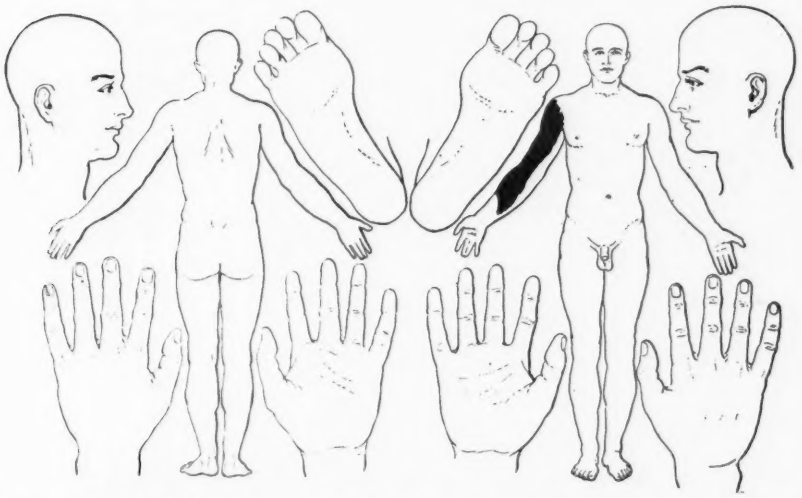

FIG. 7. L. N. Admitted immediately after accident in which he sustained a charred burn of the right forearm and arm. The flash ignited his clothing, and as a result of this he suffered a second degree burn of the trunk. Shock followed. Albumin, red blood cells and casts appeared in the urine, and visual defects, which persisted, for several weeks, were noted. All wounds eventually healed, and recovery was complete.

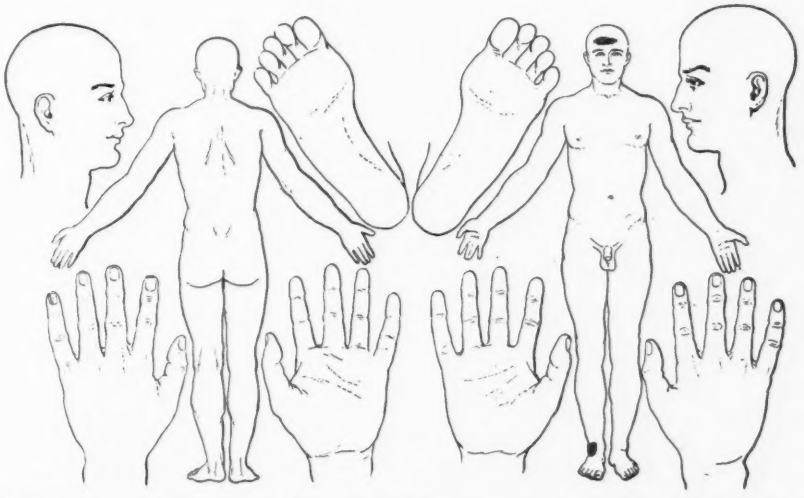

FIG. 8. J. R. Admitted within an hour after the accident in which contacts were made with right ankle and forehead. Second degree burns only were sustained. No complications developed. Observation discontinued after three days, and patient was therefore discharged from hospital. Recovery was complete.

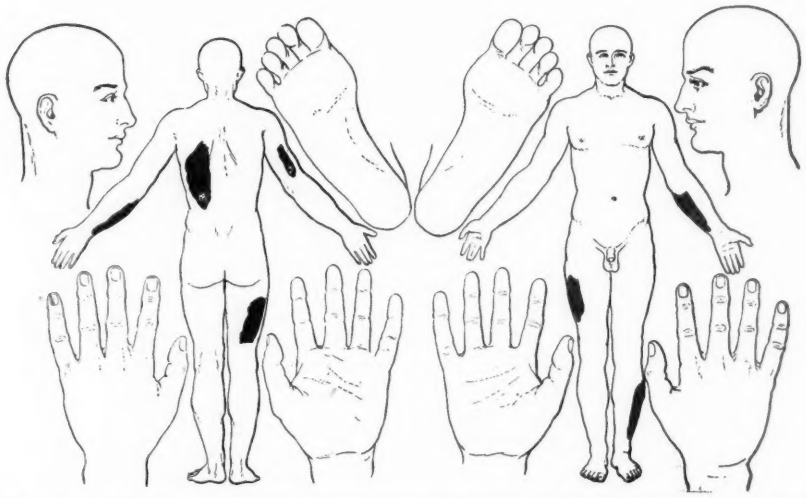

FIG. 9. A. M. Patient suffered deep charring burns of the left forearm, left side of back, and left leg, posterior surface of right thigh, and right arm. The coagulum separated slowly. Wounds were then prepared and skin grafts applied. Patient was discharged from the hospital about ten weeks later. Recovery was complete, and he was able to resume former duties.

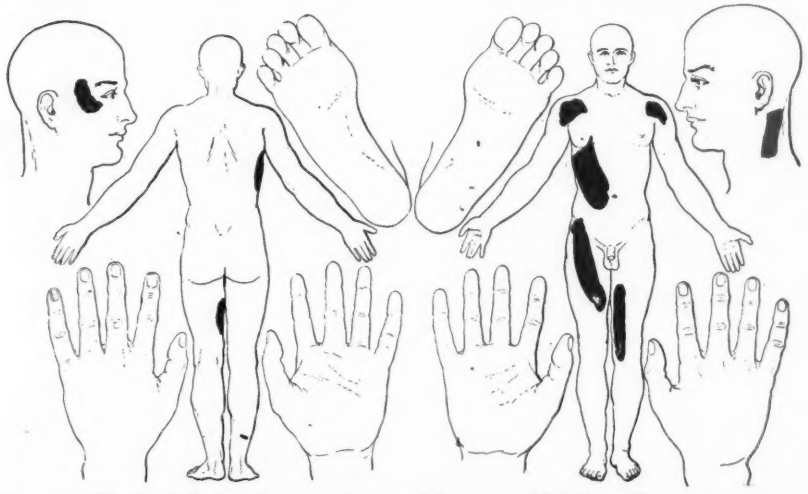

FIG. 10. W. R. Admitted soon after accident in which he fell across a 2,200-volt wire and suffered deep, penetrating, charring burns of the right side of the face, right shoulder, right chest and abdomen, right inguinal region, and anterior surface of right thigh, left shoulder anteriorly, and left thigh internally. All wounds were serious. The soft tissue fell away from the fourth and fifth ribs, and they were removed. The right lung collapsed and a bronchopleural fistula developed. Secondary hemorrhages occurred from the wound over right shoulder and in the right inguinal region. The right zygoma sloughed out, and a cataract developed in the right eye. Patient was very toxic for six months. He remained in the hospital for eleven months, and later returned for skin grafting to chest wound. All wounds eventually healed. After cataract was removed from the right eye, there was little use of the eye. Patient was able to return to lighter duty eighteen months after injury.

possibly two, where an arc developed, exhibited unusual complications. This is probably due to the fact that in an arc the temperature is in excess of 2000°C. and such extensive damage is done that death will almost inevitably follow.

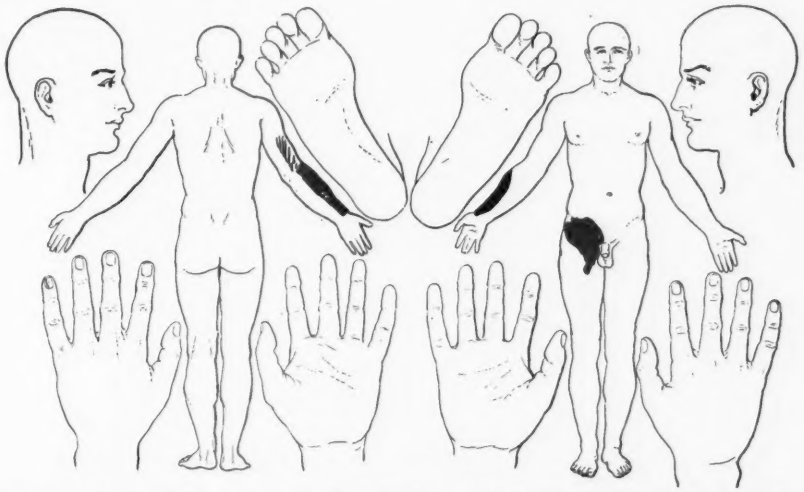

FIG. 11. H. H. Admitted soon after accident. Suffered electric burn of radial side of forearm which extended in a spiral manner to the elbow, and from there the damage was extended up the arm as a second degree burn. There was also an electric burn in the right inguinal region, which extended down the thigh as a second degree burn. The coagulum separated very slowly. A debridement was performed seven weeks later and skin grafts applied. The hand was very badly swollen and some of the radius exposed. The wound was kept clean and finally healed, after some of the extensor tendons had sloughed. While considerable deformity of the hand resulted, the use of it has enabled the patient to be on active duty for over ten years since his accident.

Because of the kind of duties performed by electricians working about high tension wires and equipment, it naturally follows that at least one point of contact will usually be the hand, and frequently it is both hands or hands and feet.

Since, next to bone, skin offers the greatest resistance to electricity, it is a common experience to see severe burns in the hands, and, since hard, calloused skin is more resistant than thin, delicate, loose-textured skin, greater destruction of tissue must be anticipated. The tendons and ligaments come next before the super-resistant bone is encountered, and the rich vascular plexus, the best conductor of electricity within the body, is to be found throughout both the hands and feet. How perfect a set-up, anatomically, for a serious destruction of tissue, once contact has been established!

Charring of tissue is more definite and instantaneous the higher the voltage, up to 5,000 to 10,000 volts. Therefore in the some-

what lower level of high voltage current, damage to tissues, not immediately manifest by desiccation or charring, is frequently encountered. The current penetrates deeply, through skin and under-

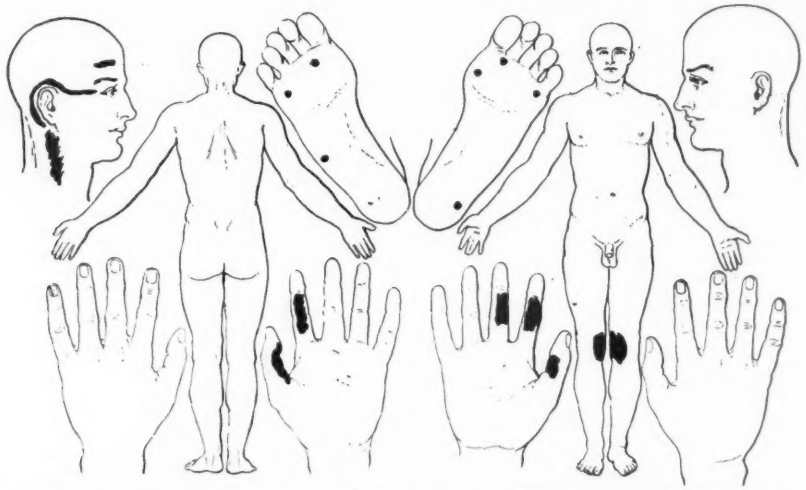

FIG. 12. W. M. Testing at transformer station. Kneeling, and when he removed pliers from right thigh pocket contacted a 30,000 volt line. He was unconscious for about one-half hour. Artificial respiration by companions. On admission there were charred burns over and behind right ear, following glasses shaft, a superficial burn from behind ear to thyroid region, where the current jumped from glasses shaft to zipper on sweater. Ischemia over each inner condyle of both femurs. These areas soon turned black. Conservative treatment employed. Azochloramid dressings twice daily. When slough had separated, one could see through the thin membrane sealing the knee joint. After healthy granulation tissue had developed, skin grafting was employed.

lying structures, often charring only the very superficial layer of skin, but enough damage is done to the tendon sheaths and tendons to set up an inflammation resulting in dense adhesions between these structures. Sometimes what appears to be a superficial injury develops into a very serious and far-reaching one, and quite the reverse is also true.

Burns over joints and tendons are often apparently trivial, but within a few days are found to be quite extensive. If an immediate debridement is undertaken the tendon sheaths and joint spaces will be opened widely, while, if conservative treatment is followed, sufficient granulation will occur to seal these spaces beneath the slowly separating coagulum.

When bone is attacked by high tension current, maximum resistance is encountered, and most of the damage is done to cortical bone. Dead bone slowly separates as the reparative process comes to the rescue, and when sequestration is complete and the seques-

trum has been removed, the area can very soon be prepared for skin grafting.

Various neurologic symptoms have been singularly lacking in this group of cases.

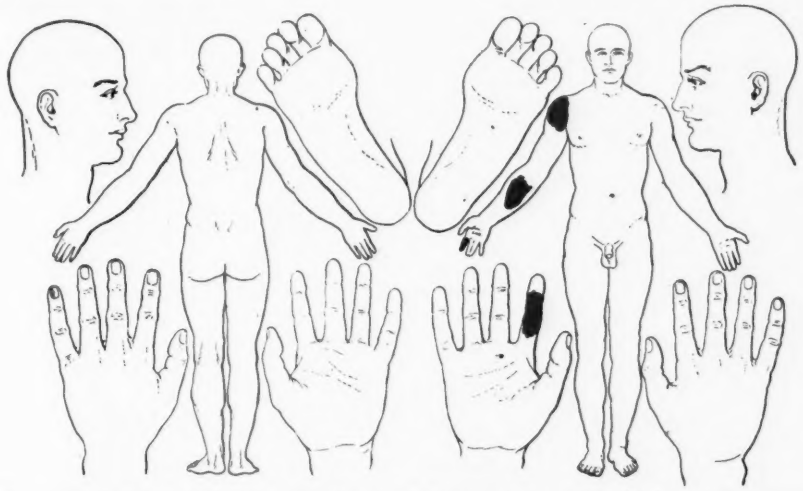

FIG. 13. T. M. Admitted immediately following injury in which contact was made with several places on right upper extremity. A voltage of 33,000 was encountered, resulting in a very superficial cutaneous charring. Recovery quick and complete.

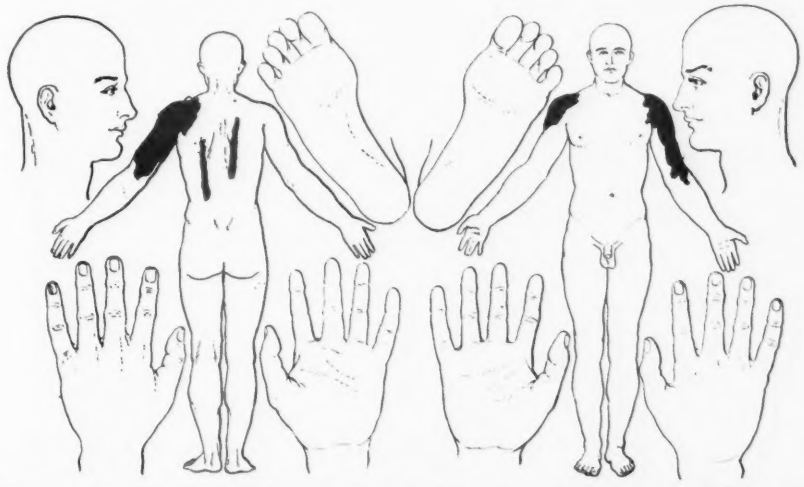

FIG. 14. G. H. Admitted soon after accident in which contact with 4,500 volt line was made with both shoulders and back. Charring followed. The coagulum separated satisfactorily, and one month after the accident skin grafting was done. Recovery was complete.

Treatment of the Local Burn. The surrounding skin is thoroughly cleaned with soap and water wherever possible, and then alcohol compresses are applied to the skin surrounding the coagulum.

When the latter begins to separate and its edges curl up, it is carefully trimmed, removing all loose sections. Then the surrounding skin is covered with vaseline or lanolin and azochloramid in olive

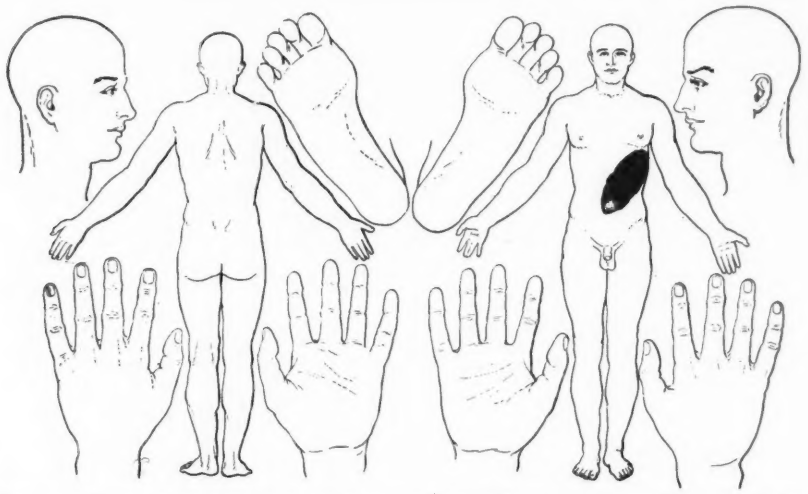

FIG. 15. Leaned against a transformer, and suffered a charred burn of the left side of the chest and abdomen. He remained in the hospital one week. No complications developed and the slough was separating satisfactorily. He was readmitted two weeks later and a debridement was done. Three days later skin grafts were applied. Recovery was complete.

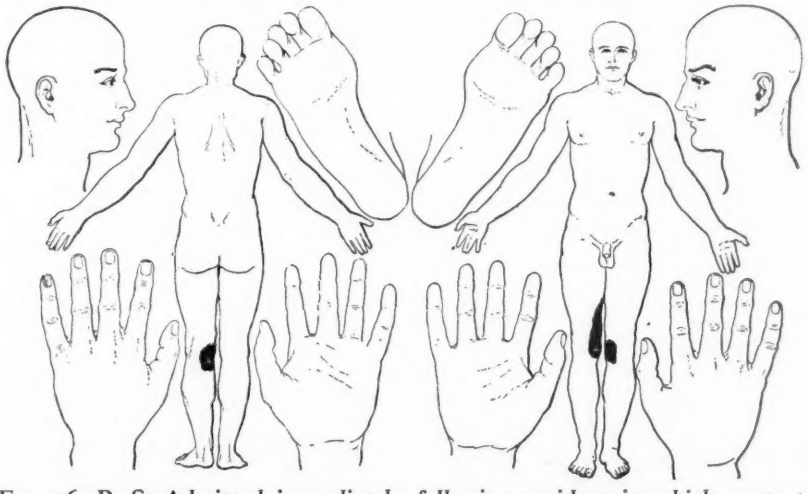

FIG. 16. P. S. Admitted immediately following accident in which contact was made with each thigh. On admission there was an ischemic area over each point of contact. Within three days death of tissue was definite and superficial. An excision of each burn was done, the wounds completely closed, and primary repair followed.

oil is applied to the ulcer. This is repeated until the entire coagulum is removed, and when the base of the ulcer presents uniform healthy granulations, skin grafting is done.

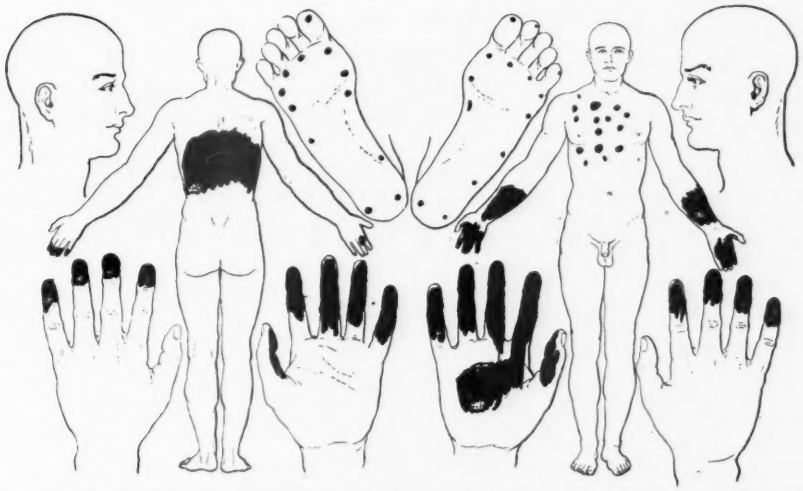

FIG. 17. R. K. Was admitted one-half hour after accident. Conscious and comfortable, but severely burned over hands, right arm, back, and chest. The burns on chest were charred discs leading to sternum and ribs, evidently the result of an arc which had split. The punched-out charred burns on feet corresponded to location of the tacks in his shoes. There was no severe shock, and patient was entirely rational and uncomplaining, exhibiting no paralysis. Seven hours later coma suddenly developed and death followed in one-half hour.

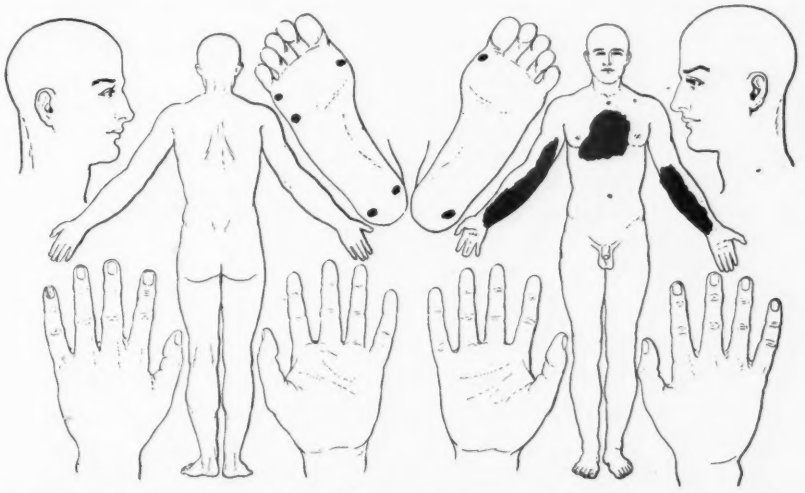

FIG. 18. H. S. Admitted immediately after an accident in which patient attempted to throw open a switch. There was a blinding flash, and he suffered an extensive burn over anterior chest wall, both arms, and penetrating charred burns on the plantar surfaces of his feet, these latter burns corresponding to the location of the tacks in his shoes. His chief complaint was tightness in the chest. Three hours later he expectorated bloody mucus, and developed a nephritis. The voltage was 26,000. His chest distress increased and death followed.

The charts illustrate the location and size of burned areas, and a short description of each case is appended. The shaded areas represent actual electric burns. Where definitely known, the voltage is stated.

CONCLUSIONS

1. Destruction of tissue due to high tension electric burns should be considered as electric burns.

2. The customary classification of burns should not be applied to those due to electric currents.

3. Immediate or early operations, such as debridement, should be employed only in the superficial, often linear type of burn, on the back or upper portion of extremities.

4. The conservative method of permitting nature to build up new tissue beneath or around the destroyed tissue leads to the most satisfactory ultimate results.

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DISCUSSION

Fenwick Beekman (New York City): All I can do is congratulate Dr. Edwards on his admirable paper. I do not think that any of us have had the experience he has had in electric burns. Mine has been very limited. I have had experience with burns, but little with electric burns. I hardly feel competent to discuss this excellent paper. I am sure I could add nothing, but might take something away. I congratulate Dr. Edwards on his presentation.

Casper F. Hegner (Denver): Dr Edwards mentioned the obscure internal effects of high tension burns. They are extremely interesting, certainly for me, for I stand here as a man who was once electrocuted. I was setting a fracture of the leg under the fluoroscope. The patient lay on the table, and around his ankle was a clove hitch with the ends around my back. I pulled on the leg and told the assistant at the head of the table

to pull the patient up. In doing so, he pulled me with the patient. There was a short circuit, and I was knocked out. My only sensation was as if a mule had kicked me in the chest. My knees were blistered, my hands were blistered, and over the heart area my shirt was burned. I was picked up from the floor and was able to continue the fracture reduction, but for about three months thereafter I had a peculiar cardiac insufficiency.

In a little experience with lightning burns, I have found that they may not leave any evidence of burns on the skin, as Dr. Edwards has shown, but they do leave cardiovascular changes. I should like to ask Dr. Edwards whether he has had any experience with the cardiovascular reactions in high tension accidents.

CHARLES REID EDWARDS (closing): I want to thank the gentlemen for their comments.

Our conservative treatment is as follows: To see that the surrounding skin is thoroughly cleaned with soap and water, dried with ether and then alcohol. Compresses are kept on the surrounding skin, certainly for twenty-four or forty-eight hours, and then sterile dry dressings until the coagulum begins to separate. At this point we cover the surrounding normal skin with vaseline or lanolin and apply azochloramid in triacetin, or olive oil. We prefer the olive oil. Dressings are repeated every day. The coagulum is permitted to curl, and then the curled, loosened edge is removed as rapidly as possible.

The cardiovascular symptoms, strange to relate, while readily produced in the laboratory and reported by most men writing on electric or lightning burns, have not been observed in any of our patients, even though they have been very seriously burned.

Of the eighteen patients that I have reported, two died. These were the patients subjected to the arc type of current and apparently there were pulmonary complications.

I did not go into a discussion of the electrical phenomena because much has been written on that. I can refer you to the bibliography at the end of my article.

The pathology has been ably reported by Jaffe and I see no necessity for further elaboration. I am simply calling your attention in this presentation to a very interesting and hazardous type of burn.

THE RELATION OF TRAUMA TO INGUINAL HERNIA

AN ANALYSIS OF 1,376 HERNIOTOMIES

JOHN J. MOORHEAD, M.D.

NEW YORK CITY

ELSEWHERE in previous publications[1–5] I have attempted to express my views on this subject. My attempt today is to analyze the operative findings in which trauma was the alleged producing factor in inguinal hernia.

The central theme is to prove statistically that isolated trauma, a single act of violence, is never the sole producing cause; further, that trauma is an aggravating factor only when and if certain criteria obtain.

Let it be understood that the subject under discussion is inguinal hernia in male adults and the relation trauma bears to the production of this lesion. There is, of course, nothing new in this inquiry, for the relationship of trauma to hernia has long been a vexing and perplexing problem and there is a vast literature on the subject, medicosurgical as well as medicolegal.

The problem is twofold. The first is the question: "Can hernia be caused by trauma?" The second the question "If hernia is not caused by trauma, can it be aggravated thereby?" In other words, we seek to determine: (1) causation, and (2) aggravation.

1. *Causation.* Can one act of trauma become the sole producing factor in the development of a hernia? This question is scarcely controversial because there is now general agreement that no single, isolated or individual act of trauma is causative in a normal individual unless there is actual laceration of the overlying structures. This virtually implies incisional hernia, compound or open wound hernia, if you prefer, and that sequence of injury is so rare as to be negligible.

It is universally conceded that a hernia does not and cannot develop in the absence of a preformed sac, and to that degree hernia is born and not made. In other words, there is a congenital predisposition or an acquired anatomic defect leading to the formation of the peritoneal pouch, the diverticulum of peritoneum that we call the sac. In the absence of this peritoneal irregularity, this bulging of the visceral covering, there can be no protrusion of it

through potential openings and hence, there can be no herniation. This doctrine of a preformed sac is established by abundant anatomic and surgical proof. There is no controversy in answering question 1 by stating that trauma is unrelated to the causation of hernia in the absence of demonstrable laceration of the overlying structures. No amount of cross examination can shake this fundamental assertion.

2. *Aggravation.* Can trauma aggravate, accelerate, accentuate, increase, modify, hernia? The answer is "Yes," if the attending circumstances so indicate.

What are these "attending circumstances"? There will be no controverting the assertion that the main essential is increase of intra-abdominal pressure. Only one other element, in the absence of penetration, could be equally productive, and that would be deliberate or purposeful dilatation of the external ring, the inguinal canal or the internal ring. That very procedure is still accomplished by professionals in certain countries where military service is obligatory and where the presence of hernia is sufficient cause for rejection.

But that contingency does not interest us and it is mentioned only to show how difficult and painful it is to interfere with these well-guarded openings by attempting suddenly digitally or instrumentally to dilate them from without. In passing, let it be stated that these professional dilators often make three attempts before they are successful, and in the process they inflict enough pain to cause the victim to faint. The suggestion and implication is that if deliberate dilatation is so painful and disabling in a prepared and desirous subject, how much more painful must be the process in an unprepared subject? In other words, sudden onset by unexpected force must, in accredited cases, be accompanied by pain and other symptoms.

If intra-abdominal pressure is the prerequisite, we can postulate our problem by the statement that this pressure must be adequate in degree and adequate in effect. Hence, there must be sufficient force to register in terms of sudden increase of intra-abdominal pressure in order to produce dilatation of a ring, or to produce a protrusion between the rings. There can be no hernia unless there is dilatation of a ring, of the canal, or of muscle and fascial coverings.

Elsewhere[4] I have called attention to the resemblance of the birth canal to the inguinal canal, the internal os resembling the internal ring, the external os the external ring, and the cervical canal resembling the inguinal canal. If impregnation and growth

occur, then intra-abdominal pressure in the one case produces the fetus, and in the other, the hernia. But the prerequisite in each case is impregnation, growth and intra-abdominal pressure.

An obstetrical analogy of this sort is quite apt and no one familiar with the subject would say that the last pain produced the fetus, although some doctrines regard the "last pain" as the producer of the hernia.

Then, if intra-abdominal pressure is the essential, what constitutes force enough to be regarded as actually causative? This can be summated in terms of *adequacy* as to site and *adequacy* as to effect. A light blow on the upper abdomen should be less productive than a heavy blow on the lower abdomen. A distant blow, a wrench, a sudden strain, a violent cough, a valiant sneeze, straining at stool, extreme vomiting, lifting, pushing up or pushing against—all these, singly or together, have been accused as causative. The relationship of any or all of them has often been so apparent that practically all the laity, and many of our profession, believe that the cause and effect are indisputable.

Let us pursue this idea still further. It is certain that many individuals are so built that, sooner or later, a hernia will develop. This we know because of laxity of the abdominal wall, paucity of muscular and fascial supports, clefts or apertures in muscle or fascia, associated varix, and a variety of congenital or acquired defects which weaken this anatomic section. Thus regarded, hernia is a ptosis. Further, we know that many persons have hernia and know nothing about it. As proof of this, the Surgeon-General's office informed me that of 2,754,000 men examined for duty in the Great War, 4 per cent between the ages of 21 and 30 had a hernia well enough developed to cause rejection for military service. If this is true in men less than 30 years of age, how many more must there be in the decades beyond 30? Further, one examination may not be enough, for we all know that the sac may, at times, be unoccupied by intestine or omentum and thus escape detection, and yet at another time become perfectly apparent. Many times I have had patients referred to me by a competent examiner who diagnosed hernia, and yet, despite all sorts of straining, jumping, pushing and coughing, it has been impossible for me to demonstrate the protrusion stated to have been palpable or visible, or both. The sac may be there, but, unless filled, it escapes detection. To be effective as a producing factor, the intra-abdominal pressure must be adequate to fill the sac and perhaps propel it sufficiently to bring it into view or into palpatory reach.

To carry out the obstetrical analogy, it must become a dilating agency sufficient to make apparent the presenting part. Hence, if this element of *adequacy* prevails, it needs no argument to sustain the view that the *effects* of this pressure must also be adequate.

In any form of trauma there is no incubation period; the cause is immediately succeeded by the effect. The sudden onset produces the sudden effect, and there is no interval or waiting period in any traumapathy.

What are these effects? *Pain*, obviously, is the first and this should register enough and be sufficiently disabling to make the possessor aware of it at once. Even under local anesthesia in a patient dulled by morphine or barbital, we cannot at operation handle the sac or its contents without producing pain. If we cannot do it then, how is it possible for a hernial sac of recognizable size to appear without pain? And if the pain is not disabling, or is transient, and unaccompanied by nausea, imminent syncope, testicular dolor and other appropriate signs, are or are we not justified in saying that the traumatic act in question was incidental and not productive? The answer is self-evident, unless we are willing to scrap all we thought we knew surgically and anatomically of this section of the body.

If a man comes to me the day after he says he received his hernia by a lifting strain, and he tells me he had some pain, but not much, and he kept on working, and that night he "found a lump in the groin," can I, as an examining surgeon, expect to find clinical proofs to link the "strain" with the "lump?" Yes. What are the proofs? *Swelling* is one, perhaps *ecchymosis. Local tenderness* is another. Inability painlessly to palpate the protrusion, or to introduce the finger into the ring are other signs, for we all know so richly endowed a section will not fail to resent our examination in terms of pain and tenderness. What am I seeking to determine? Actually, the patient must have sustained an acute peritonitis or diverticulitis if this asserted "strain" bulged into the preëxisting sac to the extent claimed. Now, no medical man within hearing will assert that a segment of peritoneum can be violently thrust from its normal habitat without resenting it unmistakably, and announcing it by appropriate signs and symptoms.

Let us go on and operate upon this patient, note the findings, make a biopsy and send the sac to the laboratory.

With the patient under spinal anesthesia the modified Bassini or Ferguson operation is done. Assuredly, if the condition is recent, a week old or less, one should find corroborative evidence, such as

exudate, organized hemorrhage, traumatized muscle or fascia, and an inflamed sac that has been separated from the contiguous structures of the cord. I have operated on several so-called traumatic herniae as early as a few hours after the alleged onset, but never have I found the slightest evidence of recent pathology. The thick or thin sac was adherent, it had to be dissected, the contents were often shaped or moulded, suggesting long occupancy, the base of the sac was wide and easily dilated. Frequently the contents were attached by strong bands and in every respect, *aside from the history*, there was not a single vestige of surgical proof to indicate anything recent. Then the sac was sent to the laboratory and shortly the report came back, disclosing chronic peritonitis and fibrosis of a grade that would take a year or more of friction and circulatory reëstablishment to accomplish.

This sequence does not occur occasionally, but it is the persistent rule, the inevitable chain of events. Therefore I long ago gave up the idea that hernia was connected with injury except under the most unusual circumstances.

My assistant, Dr. Louis R. Slattery, has analyzed 1,376 herniotomies performed by me, and I am indebted to him for this laborious survey, the details of which were published.[3]

As to operations, we may summarize our experience as follows:

1. We do not transplant the cord.
2. We do not use fascial transplants.
3. We favor spinal anesthesia.
4. We enforce deep breathing exercises when the patient is out of anesthesia.
5. We do not permit catheterization.
6. We regularly get the patient out of bed on the eighth or ninth day to prevent disuse muscular atrophy.
7. We permit return to light work two weeks after the patient leaves the hospital, and two weeks thereafter he is returned to regular work.
8. We do not believe in the efficacy of the injection treatment except in carefully selected, coöperative patients under the care of experienced surgeons.

Thus far we have alluded to the anatomic fallacy of believing that hernia could by one act of trauma assert itself, and we have also referred to the biopsy evidences at operation, and also stated the pathologist's findings. Thus, we have arrayed the anatomist, the clinician, the surgeon and the pathologist in agreement.

Are there further proofs to add to this disclaimer? Yes—and these are from the book of experience, the great teacher.

I do not think we are wrong if we estimate that 10 per cent of our male patients in the decades 20 to 70 have actual hernia, and we know, statistically, as stated, that 4 per cent in the 20 to 30 decade have the condition to an easily recognizable degree. If this is so, then a very considerable proportion of your patients and mine who are treated for other injuries have actual or demonstrable hernia.

Granting this, the inference is that with violence enough to fracture the pelvis, the ribs or the femur, there should be an occasional instance of aggravation of an already existing hernia.

Have you ever been called upon to treat such an aggravation as a concomitant of injuries that inevitably must have produced extreme intra-abdominal pressure? We have all seen crushing injuries of the abdomen and of the chest, with and without intra-abdominal and intrathoracic damage, but I am unaware of any case reports indicating aggravation of hernia. To me, this is one of the very real proofs that aggravation, even under extreme violence, is not a very active factor; and if violence sufficient to rupture viscera and fracture a pelvis or hip does not cause aggravation, it is not surgically logical to ascribe aggravation to lesser causes. Personally, I have never had a patient who required attention for hernia in the presence of associated injury contiguous to or distant from the inguinal regions.

Another point seems worthy of note, and that is the infrequency of strangulation of a hernia under the influence of strain or injury. The majority of my cases of strangulated hernia have occurred at night or outside working hours; and, incidentally, strangulated hernia seems less common than hitherto. If aggravation due to violence, was an important factor, then assuredly strangulation as a sequel should be more common.

However, we are accosted by the clinical fact that pain does occur after some definite act or incident associated with intra-abdominal pressure; and that, in some cases, a lump appears within a few hours or a few days. What causes the pain and what causes the lump? *Pain* can be due to tugging or pressure on the sac, to gaseous distention of the intestine within the sac, to rotation or twisting of the omentum in the sac, to pulling upon the adherent contents of the sac, to irritation by pressure upon the iliohypogastric or ilio-inguinal nerve supply, to muscular strain, and perhaps also to torsion of the cord.

The *lump* appears because the sac is occupied by intestine or omentum, or both, and it then acts like a Barnes or Voorhees obstetrical bag to dilate the orifice or the canal—virtually a prolapse. But, as stated, neither the pain nor the lump denotes recent origin unless corroborated by local tenderness, edema and perhaps ecchymosis.

Hernia is not actually an acute surgical entity, but, in reality, a progressive disease characterized by periods of remission and exacerbation. Inevitably, the lump will appear if the already mentioned factors pertain, and sooner or later, peristalsis will balloon the sac sufficiently to make of it a dilating agency. The accused intra-abdominal strain or injury may be the *ascribed* factor in the opinion of the patient, but the *ascribable* factor is the normal development of a progressive disease, manifesting itself by an exacerbation.

As physicians, we often have to differentiate as between the *ascribed* and the *ascribable* cause. A patient may *ascribe* his attack of abdominal cramps to a fish dinner, but any physician would assert that the symptoms were *ascribable* to an exacerbation of gallstones or appendicitis. Assertion is not proof; the *ascribed* is not always the *ascribable* in any intra-abdominal lesion, hernia not excepted.

In differentiating, then, as between an old and a new hernia, there are certain criteria, certain proofs based on professional knowledge, to which we should give heed. (Table 1.)

TABLE 1
CRITERIA

	New Hernia (Acute)	Old Hernia (Chronic)
1. Type of injury	Intra-abdominal pressure from contiguous impact	Ditto from remote impact
2. Type of person	Muscular	Non-muscular; ptotic build; fat
3. Time of onset	Immediate	Late
4. Type of symptoms	Pain; nausea; tenderness; edema	Slight, if any
5. Physical findings	Tenderness; swelling; ecchymosis	Absent or slight
6. Operative findings	Hemorrhage; edema; no adhesions; no diastasis, slits or lipoma	Adhesions; extra- and intrasaccular diastasis; slits and lipoma
7. Pathological findings	Acute peritonitis; hemorrhage	Chronic peritonitis; fibrosis

All this has a medicolegal bearing and we often are beset with doubt in attempting properly to allot responsibility. The compensa-

tion laws in some states require definite surgical proof before making an award, and the seven criteria named above are some of the main factors in the determination. In most industries, a preëmployment examination is required and then the applicant is rated as to hernia in some such terms as:

First degree hernia—External ring admits the tip of the index finger.

Second degree hernia—Ditto, plus impulse, plus gaping ring.

Third degree hernia—Ditto, plus lump.

Fourth degree hernia—Ditto, plus lump below external ring.

The question of repeated violence, successive intra-abdominal pressure, and continuous or intermittent strain is, of course, an important element in those predisposed, and in this group it is only a question of time until the process assumes recognizable proportions.

It is surprising, however, to note the frequency of obvious hernia without the possessor being aware of it. Once attention is called to the finding the almost inevitable comment is: "I must have strained myself"; or "I remember lifting something a short time ago."

Repeated intra-abdominal pressure is sometimes an accredited causative factor. Incidentally, under spinal anesthesia, with the canal opened, it is interesting and instructive to ask the patient to cough or strain. In so doing, the sac is ballooned in the same way as if the patient becomes nauseated during the operation.

My conception of the development of hernia is that the preformed sac enlarges. It then acts as a dilating wedge and at the appointed time presents itself as a completed product, palpable, and perhaps visible to the physician and to the patient. That it may occur as the outcome of a single or multiple traumatic agency is not to be decided until the extent of the intra-abdominal increase is estimated in terms of *adequacy;* if adequate, then the ensuing symptoms are immediate and demonstrable.

In passing, it is pertinent to say that the surgical cure of hernia has also a bearing on its causation. No experienced operating surgeon has failed to note the extensive pathology involved, the nature and diversity of which required years, and not days or weeks, to produce. Further, there is often a congenital absence of the normal protective barriers, and we oftentimes note a wide inguinal triangle or a very thin or imperfect conjoined tendon. Again, other cases show wide separation in the fibers of the internal oblique and definite slits or thinning of the external oblique fascia so that it looks like bacon with the muscle appearing under the fascial aper-

tures. Not infrequently varicosities of the cord act as the dilating agency, to say nothing of that large group in which lipoma of the cord may act as a wedge to force the contiguous structures apart. Obviously, none of these findings can be said to be in consonance with any recent occurrence, for all of them are congenital or slowly acquired.

It has been said that direct hernia is more likely to be acute than indirect hernia, and that scrotal hernia is the patriarch, the ancient of ancients. Bilateral hernia assuredly is practically never acute, and about 60 per cent of my patients have had hernia on both sides. Furthermore, a direct and indirect hernia on the same side scarcely can be called acute, for to produce such a sequence by one act of violence implies great force and inevitable great effect, in terms of disabling pain that should send the patient into a state of shock.

It is a surgical fallacy to believe or to assert that any single act of trauma can, without symptoms, bulge the sac and propel it through normal openings or along the canal in an area so richly endowed with a vascular or neural supply, and so well buttressed by strong muscles and fascia. The sac is a diverticulum and when it suddenly bulges, it may be regarded as producing an acute diverticulitis. If so, it registers like any other diverticulitis, namely, by pain, swelling and tenderness. The appendix is the best known diverticulum and the cardinal symptoms of appendicitis are the well known trinity of pain, swelling and tenderness—just as in "hernia-itis." I am aware that "traumatic appendicitis" is also an interested party in medicolegal controversies, but I have never seen it at the bedside. It has about as much standing as "traumatic tonsillitis" due to hanging or a blow on the neck.

SUMMARY

1. Hernia is never *caused* by injury; the preformed sac is always an antecedent.

2. Hernia can be *aggravated* by injury if the source and symptoms are *adequate.*

3. Immediate disabling pain is the chief symptom, and this is associated with nausea, tenderness, swelling and other manifestations resembling peritoneal shock.

4. At operation, the findings usually denote an ancient process, as indicated by adhesions, extrasaccular and intrasaccular.

5. The pathologic examination of the sac demonstrates chronic peritonitis and fibrosis.

6. Hernia is a chronic progressive disease, a ptosis, a diverticulum, and not an acute surgical entity except in very rare instances.

7. A large proportion of our adult male population have hernia and do not know it; and we, as surgeons, do not know it either, when we are treating them for contiguous injury grave enough to cause aggravation if trauma is a common accelerating factor.

8. Like osteomyelitis, once a hernia always a hernia, and it is subject to periods of accession and remission.

9. If trauma is to be accused and found guilty, then there is always plenty of reliable evidence. This need never be medicolegally seductive nor speculative, but rather, medicosurgically deductive and positive.

10. Trauma has burdens enough without being saddled with this ancient heritage which modern traumatology should cast into the discard along with grape seeds as a cause of appendicitis.

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DISCUSSION

Philip H. Kreuscher (Chicago): The Compensation Act in the State of Illinois provides that before any employee can claim a traumatic hernia he must prove beyond a shadow of doubt that there was no preëxisting hernia. He must also prove that there has been a trauma. Furthermore he must produce evidence of trauma, such as discoloration, swelling, ecchymosis, pain and immediate incapacity.

Despite all of this, the arbitrators and commissioners in Illinois still give compensation to our employees when they have hernias, and in my opinion base their judgment on the clinical history alone. I have in mind one patient in particular who claimed a hernia from lifting. However, according to the clinical story, he was lying under an automobile with both his thighs flexed on his abdomen and in that way was pushing upward on some portion of the car. It is difficult for me to conceive how a hernia could possibly occur under these conditions since the pressure of the thighs upon the inguinal area would, it seems to me, make it impossible for herniation to take place.

In the Carnegie Illinois Steel Corporation we offer an operation free of cost to our employees without actually accepting any responsibility for the occurrence of the hernia.

Frank P. Strickler (Louisville): Dr. Moorhead has had a very rich and extensive experience on this subject, and his paper is excellent. After

reading this paper, one could hardly doubt that hernias are of congenital origin and that trauma aggravates an existing hernia. Any difference of opinion I have with Dr. Moorhead is trivial and does not amount to much.

We have a very happy situation in Louisville. Most of our laboring men are American citizens, employed by American citizens, and when a hernia occurs, it is usually taken care of. The medicolegal aspect rarely enters into the situation. The man goes to the hospital, a surgeon fixes the hernia, and that is the end of it. The insurance company pays for it. I think this is done because it is easier to repair the hernia than to fight the case.

We always transplant the cord. Very frequently a very thick, heavy cord is encountered and it is, in my opinion, necessary to transplant. Better union results when we do it. If the cord is very thick and heavy, we occasionally transplant it externally to the aponeurosis of the external oblique just under the skin.

As anesthetic we use cyclopropane. We usually use kangaroo tendon as suture material, a technique taught by the late Dr. W. B. Coley. I see no reason to change it, although I understand they are now using silk at the Hospital for Ruptured and Crippled. In some cases we use fascial sutures, taken from the external oblique or sometimes from the fascia lata. In using the latter, we always expose the fascia lata and take our sutures under direct vision, because we have had some bad results with fascia strippers. Sometimes there is hemorrhage or a big hematoma after using them.

We are a little more conservative than Dr. Moorhead, in that we keep our patients in bed about two weeks and let them go back to work about a month later. Complications we have had have usually ben pulmonary infarcts, and, occasionally, infection.

I mention the injection method of treatment only to say that, in my opinion, it is not what it is supposed to be. I do not approve of it.

Dr. Moorhead has written an excellent paper; the points I have mentioned are merely pertinent reflections.

ARTHUR R. METZ (Chicago): Dr. Moorhead has well stated the facts on the subject of traumatic inguinal hernia. Any surgeon with extensive experience will agree with the views that he has expressed.

In our experience, involving over 1500 cases of inguinal hernia, we have never had occasion to operate in a case of traumatic hernia. There have been injuries to the abdomen which resulted in rupture to the stomach, intestines, liver, spleen, kidneys and bladder, but in none of these cases has a hernia been produced as a complication. If a traumatic hernia can be produced it certainly ought to develop in connection with these more serious injuries to the abdomen.

In a careful survey of 12,300 men who are actively working, it was found that 6.4 per cent have inguinal herniae. In the same group of men another 7.6 per cent have large inguinal rings and are potential hernia victims. These two classes total 14 per cent of employees in this group who are

possible subjects for a hernia operation at some future date. Only 1 per cent have been operated on for hernia; the others are doing their normal work and are not considering operation.

Everyone interested in the subject of inguinal hernia should review Dr. Moorhead's paper, after which the alleged "traumatic inguinal hernia" will be dropped as a surgical term and will be known in its true state as a congenital inguinal hernia.

EDGAR GILCREEST (San Francisco): We can have nothing but praise for this scientific paper from the anatomical and embryonic viewpoint. We are probably all in thorough agreement with Dr. Moorhead's conclusion that hernia is congenital, but there is a practical point which I think should be emphasized. One thousand bookkeepers will not have so many hernias as one hundred longshoremen or brakemen; therefore, we must concede that the type of work these men are doing plays an important rôle in the causation of the disability. As practical surgeons, we must answer this question in cases of litigation. Therefore, if we admit, as Dr. Moorhead does, that trauma aggravates a preëxisting condition, this, after all, is the salient point. If we make this clear, industry will rely upon the surgeon to say which men to reject and which to employ. When industry hires workers, I think it takes them for better or worse. When men are examined before they are put to work, the surgeon may decide which men have hernia and which have not. The question of traumatic hernia will be relegated to bygone days.

JAMES A. JACKSON (Madison, Wisconsin): I think that most surgeons of trauma are agreed on the point that there is not such a thing as traumatic hernia. However, how much does this avail us if the Industrial Commissions in certain states hold that there is?

In the State of Wisconsin many years ago, I testified that there was no such thing as a traumatic hernia. However, the case was decided against me and they had a rather unique explanation. The Commissioner admitted that the man had a sac previously, although he had never felt any bulging. At this stage it was a potential hernia, he ruled, which had become a traumatic hernia when the content was forced down. Therefore the company had to pay for it.

This was a new conception to me, but the ruling has been followed in case after case.

I think it would be well if some of the Commissions could have Dr. Moorhead's splendid paper read to them; they might change their ideas on it.

Speaking of the injection method of treatment—there are in our Clinic three Jackson brothers. My younger brother, Arnold, has used injections in some 600 cases of hernia. He is very fair about his statistics and thinks his results so far, over a period of about five years, compare very favorably with the operative treatment. My older brother and myself are not entirely

convinced of the efficacy of the injection treatment—the only trouble is that we do not get hernias to operate any more; the younger brother injects them all.

D. C. PATTERSON (Bridgeport, Conneticut): I was very much interested in Dr. Moorhead's paper. I fully agree with him in every point he makes, except perhaps in the non-transplanting of the cord.

I had mixed feelings when I heard Dr. Strickler state that they had no trouble in Kentucky—"they fixed the hernias and that was the end of it." We occasionally get recurrences.

In regard to the injection treatment of hernia, for the last three years I have been interested in this method, principally to determine for myself whether or not the procedure had any value. It has been hard to credit the statistics that have come from the west; in the East we have been slow to adopt the method. Statistics have run from 4 per cent to 98 per cent of cures, and such figures are too fantastic to credit. The injection treatment has, I believe, a small place in surgery, and surgeons should undertake its administration. No one unfamiliar with the anatomy and pathology of hernia should attempt the injections.

I have used the injection method only in simple, indirect, inguinal hernias. I cannot conceive of its application in the average direct hernia. I would not think of injecting a femoral hernia, because it is impossible to tell whether the contents of the sac are reduced, and it is almost impossible to get a truss to hold a femoral hernia.

Some of our patients have been at hard labor for over two years since their injections and are now free from hernia; others have failed to get closure. Why anyone would want to undergo the trouble and nuisance of the injection treatment I do not understand, because it means wearing a truss day and night for at least two months, and then only during the day for the next five or six months. The injections are not always painless. We have never had any severe complications, but in quite a few cases the patient has complained of pain. The advantages of the method are primarily economic.

A little over a year ago I encountered a non-inguinal hernia which occurred after a clear cut history of trauma. A man about 50, a bank cashier, stooped to lift a ledger from the safe to a high desk, and as he did so he was distinctly aware of something ripping in his back. He had no pain, he said. He thought it was his vest or shirt ripping and let it go at that. In about three weeks, he began to have a little discomfort in his back. This grew a little more intense, and after a month he went into contortions before a mirror, trying to look at his side. Finally he perceived a slight bulge in the lumbar regon. The pain continued and nine months later I saw him. There was a definite and slightly tender bulge when he would bend over and produce tension on the side. At operation I found a protrusion of fat which could easily be reduced, but would reappear on straining. There was a

small tear, perhaps ¾ inch long, in the fascia, in the upper triangle of the lumbar space. We repaired it, and he had no further trouble.

This case, I feel, was of traumatic origin, and it is the only case of upper triangle lumbar hernia that I ever saw.

RALPH G. CAROTHERS (Cincinnati): I think we all agree that Dr. Moorhead has presented a brilliant paper; we all agree there are a great many hernias and that they are a surgical problem. However, the the discussion has brought out the fact that they are brought out social rather than industrial problems. What difference does it make in the long run whether industry pays for the operation, or whether the government takes the money from industry and operates on the fellow through state funds?

We must get these thousands of people operated upon, or injected, or trussed, or out of the way somehow or other, and Washington is going to see that the country pays for it in one manner or another.

HOMER D. DUDLEY (Seattle): Dr. Moorhead has not made a single controversial statement from a purely academic point of view, but how we may apply our services to the public is another matter.

It has been my privilege to examine every applicant for employment with a large company over a period of eighteen years, particularly to determine whether or not there was any likelihood of the applicant's developing a hernia. All of the employees, about 400, have been examined every one to two years, and of that group two have developed hernia from alleged physical effort of a competent cause. Both were operated upon and there were findings to indicate each had a congenital predisposition to the development of hernia.

In the State of Washington it makes no difference what we surgeons believe. The Supreme Court and the Workmen's Industrial Compensation Committee have decided that a workman with a hernia who says he didn't have it prior to any given act or physical effort has a hernia in the eye of the law and comes under the provisions of the Medical Aid Act.

We also have an affidavit form referred to by Dr. Kreuscher which would seem to indicate that there could be excluded the group particularly predisposed to hernia or patients who might have had a hernia. However, all get operated upon and are awarded benefits just the same. The affidavit has been a waste of time and effort, and I believe it has been abandoned.

I have testified in court in regard to all of Dr. Moorhead's criteria, but, unfortunately, no credit is given them by juries. The jury decides that if a man did not have a hernia before the alleged accident and had one afterward, the injury or accident must have been the cause.

Possibly, if an acceptable form could be developed whereby some evaluation could be made between the predisposing factors in the individual

and the disability attributable to injury, there might be some method of presenting this to the courts so that an award could be made only for the percentage of disability due to the injury.

JOHN J. MOORHEAD (closing): This does not seem so much like a closing as it does an opening. It looks as if we had started something.

The first sentence which I used in this paper was to the effect that this was a controversial and perplexing question. That seemed to be borne out a good deal by the discussion.

I may say that in so far as the Compensation Board in New York is concerned, it does not make very much difference what our preconceived notions are, or what the anatomic basis may be, or what the surgical or pathologic findings may be. Their viewpoint is—the man didn't have it before he got hurt; he has it now—and that is the end of that.

It seems to me if an organization like this one could put itself on record from a clinical standpoint, based on the experience of such a large group as this in respect to some of these controversial problems, we would render a real service.

Is there such a thing as a traumatic hernia? Is there such a thing as traumatic appendicitis? Is there such a thing as a traumatic goiter, or traumatic tuberculosis, or traumatic malignant disease? Do we see it? And if this group does not see it, where is it? It seems to me that is one thing that eventually this organization could give itself over to and do a very useful piece of work.

In regard to the bed period for these patients, I remember some years ago we used to keep our cases of appendicitis in bed for four weeks. It got down to two weeks, then ten days, and some people get them up in twenty-four hours. I have gone through exactly the same experience in regard to my hernia cases. I do not see the use of keeping a patient in bed for a period of three or four weeks. My patients develop a disuse of the muscles of the abdominal wall if I keep them inactive too long. My experience is that I get fewer recurrences when I apply the principles that I have just narrated than I did hitherto.

The same applies to the transplantation of the cord. I dislike interfering with the deeper structures, as varicocele or enlargement of the testicle may result, which defeats one of the objects of operation. I cut down the size of the cord sometimes if it has a lipoma or too many veins, but ordinarily I believe it is the result of a failure of circulation, that if I can restore the parts and get the sac out, then that will spontaneously take care of itself.

In relation to white collar labor by comparison with hard workers, the proportion is not so great as you might think. I have a great many patients who are employed in banks in New York City, and the ratio of hernias in that white collar group to the hard-working class is very sur-

prising. I think the thing basically comes down to the anatomic type of the individual.

That goes for the kind of employee to reject. We have bases of preëmployment requirements, but I must say that I am amazed to see how great a number who come in with dilated rings and potential hernias have gone on with hard jobs and yet have had over the years very little in the way of aggravation.

I use no support after operation; I do not use this in any form of laparotomy.

As to proof of aggravation caused by a particular accident, I lay particular emphasis on the question of pain. This is very largely a social as well as a surgical problem.

I do not believe that hernia is a universal bar to employment; as I have already indicated, I know a great many men who are doing laborious work with hernias on their way, who are carrying on their jobs quite effectively.

TRAUMATIC RUPTURE OF URETHRA

WILLIAM J. CARSON, M.D., F.A.C.S.

Surgeon, St. Luke's Hospital

MILWAUKEE, WISCONSIN

"WE are dealing with a very grave and desperately urgent accident, where simplicity of technique is of paramount importance," said Hamilton Bailey of urethral rupture.

Rupture of the urethra may be due to external causes, such as gunshot wounds, stab wounds, blows, falls or crushing injuries, with or without fracture of the pelvis. Vincent O'Conor, reported in 1936 eight cases of rupture of the urethra due to falls astride manhole covers. A careful review of the literature failed to reveal other reports of this type of accident as the cause of urethral traumatism. The blow received by the perineum in these cases is severe because the metal cover is swung violently upward and strikes as the body is lurching downward and forward.

Internal injuries causing urethral rupture may be the passing of instruments, the presence of a foreign body or large rough calculi.

Partial or complete ruptures are classified anatomically as: (1) pendulous, (2) bulbous—anterior to the trigonal ligament; (3) Bulbomembranous—anterior trigonal ligament; (4) membranous portion posterior to the triangular ligament.

Extravasation follows the fascia planes. In lesions anterior to the triangular ligament it spreads over a route limited by Colles' fascia in the scrotum, perineum and penis and in the abdomen by Scarpa's fascia. If the lesion is posterior to the triangular ligament the extravasation involves the retroprostatic region and invades the upper inner aspect of the thigh, the ischiorectal fossa and the buttocks. If rupture is between the layers of the triangular ligament, extravasation may spread externally or toward the pelvis. When intrapelvic rupture is present, it extends to the prevesical and perivesical region.

CASE REPORT

On July 16, 1936, Dr. H. A. R., age 63, while visiting at the home of a colleague, stepped backward out of a car upon a loose cover plate of a manhole which turned. His left leg went down into the manhole, and the perineum struck the edge of the manhole cover.

Examination at Columbia Hospital, one hour later, revealed marked infiltration of blood in the perineum extending completely around the anus and over the inner side of each thigh and into the dorsal surface of scrotum, with bleeding from the meatus. The pulse was weak thready, 120 per minute. Rectal examination revealed a large hematoma the size of an orange extending from the perineum to the apex of the prostate, the prostate being freely movable. A diagnosis of traumatic rupture of the urethra, accompanied by hemorrhage and shock was made.

The patient was immediately prepared for suprapubic and perineal operations. The first operation was done in lithotomy position with a filiform in the urethra. An inverted U incision was made in the perineum through the skin and superficial fascia, which exposed a large blood clot with continuous bleeding from the wound and meatus, when the clot, which had an odor of urine, was removed. The recto-urethral muscle was found to be fragmented, the finger was passed along the rami of the ischium on the left, and the filiform was found outside the urethra. The Young technique was carried out by cutting the central tendon. The filiform was then removed from the urethra and a 15 F. sound passed, which showed the urethra to be torn completely off at the apex of the prostate.

The prostatic urethra was located with some difficulty. A 22 F. soft rubber catheter was passed into the bladder, and urine and blood were obtained. The catheter was anchored to the edge of the membranous urethra with chromic 0 catgut. The torn puboprostatic ligament was then united with one chromic 2 catgut mattress suture. The distal end of the catheter was then pushed over the end of the sound and the sound withdrawn. End-to-end anastomosis was carried out, using chromic 0 catgut, all sutures being inserted before any were tied. A small Penrose drain was inserted on each side and the wound closed with through-and-through silkworm gut sutures, with a small drain in the subcutaneous fat.

A second operation, extraperitoneal suprapubic cystotomy, was then done. The bladder was filled with blood clots and a No. 30 mushroom catheter was used for drainage, with one Penrose drain in the prevesical space which contained free blood. Operative time was fifty-five minutes. During the operations 1500 c.c. of 5 per cent glucose in normal saline was given intravenously. The blood pressure rose from 70/50 to 95/55 during the operations.

At 4 P.M., intravenous glucose, 1500 c.c. in normal saline, was started and at 6 P.M. there was marked improvement in the pulse. The blood pressure was then 116/74. At 11 P.M., a blood transfusion of 500 c.c. was given by the Kimpton-Brown tube.

On July 19, 1936 three drains were removed from the perineum and one from the prevesical space. On July 23, the suprapubic tube was removed. On the tenth postoperative day severe bleeding occurred from the left side of the perineal wound, which was controlled by pressure against the perineum. The systolic blood pressure fell from 150 to 102 and the pulse increased from 80 to 120.

On August 1, 1936 all sutures were removed and the catheter was also removed from urethra. Negative suction at 5 pounds pressure was applied to the suprapubic wound. Two days later the patient was voiding every three hours, and in another two days the suprapubic wound was healed. The patient was then voiding every two hours, and was discharged from the hospital.

On August 10, Van Buren sounds 16, 18, and 20 were passed. The patient remained in the care of Dr. Alexander Randall of Philadelphia for one year. He is now in excellent health and has no stricture.

COMMENT

Verguin of Toulon, in 1757, was the first to employ retrograde catheterization. Guyon in 1892, demonstrated the value of end-to-end anastomosis. Rutherford of Glasgow, in 1898, combined suprapubic and per urethram drainage.

Partial rupture has been treated successfully by suprapubic cystotomy with retrograde splinting of the urethra by an indwelling catheter by George G. Davis, O'Conor, Hutchins, Wheeler and others. Owing to the extravasation of blood and urine and the great advantage of end-to-end anastomosis, it is advisable to do a Young perineal section with the suprapubic drainage.

During the past twenty-six years, I have seen ten cases of rupture of the urethra, including two of the pendulous; two of the bulbous; three of the bulbomembranous; and three of the membranous posterior to triangular ligament. The case reported here is the only one of complete tear in my experience.

Indwelling catheters should be used with care, as they frequently produce traumatic urethritis and cystitis, and if they extend too far into the bladder can ulcerate through the bladder wall, producing peritonitis.[3]

SUMMARY

Traumatic rupture of the urethra due to stepping on a loose manhole cover is more common than current textbooks indicate.

Treatment consists of immediate (1) suprapubic cystotomy and retrograde catheterization; (2) perineal section for end-to-end anastomosis of urethra, suture of puboprostatic ligaments (if torn) and adequate drainage; (3) treatment of shock and hemorrhage by intravenous fluids and blood transfusions, etc.

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DISCUSSION

E. T. CROSSAN (Philadelphia): My compliments go to Dr. Carson for the beautiful result of his case.

That Dr. Carson's results are worthy of comment, you will readily recognize if you have had any experience in trying to find the proximal end of a torn urethra. Furthermore, if you expect that a sutured urethra will remain in contact, you are stretching optimism.

Dr. Weil's method is directly opposite to that which has been described by Dr. Carson and again we all would be stretching optimism if we would hope to obtain the same good results as he has.

In the first place Dr. Weil has been very modest in describing how he finds the bladder; you might find it quite difficult to locate the bladder in a case of fracture of the pelvis in which there has been a great deal of extravasation of urine. Occasionally you might find that you had entered the peritoneal cavity instead of the bladder.

The point of these remarks is this: Since Dr. Weil has been able to obtain good results by retrograde catheterization and leaving the tube in place, why is it not feasible to catheterize the bladder with a metal catheter through the penis at the outset. In those cases that are seen early, the catheter may be left in place to drain. Might this not be preferable to the extensive operations described by Dr. Weil, and equally extensive operation that was described by Dr. Carson?

I know that in proposing such a method I lay myself open to many objections, in that I have not provided for the care of infection. However, the catheter which is used to drain the bladder will at all times act as a drain for the area that has been contaminated. All this depends upon success in getting the catheter in. This would seem to be the first procedure to be attempted. In a few cases we have used the method, and so far with good success.

I should like to ask Dr. Weil what he does in that type of pelvis fracture in which there is a ruptured urethra and the depression of the entire central fragments of the pelvis or the entire symphysis and the ramus of the pubis and the ramus of the ischium have descended in toward the perineum.

CARLETON MATHEWSON, JR. (San Francisco): The most important question that confronts us in traumatic rupture of the urethra is that of diagnosis, which has not been stressed by Dr. Carson. We realize that only

a small percentage of patients with fractures of the pelvis have trauma to their urethra or to their bladder, but because the percentage is so small these individuals are very apt to be overlooked.

On the Emergency Service at the San Francisco City and County Hospital a routine procedure is carried out in all patients presenting themselves with fractures of the pelvis. A voided specimen of urine is examined for evidence of gross or microscopic blood. If the patient is unable to void or if there is evidence of blood in the voided specimen, a catheter is passed into the bladder and a sample of urine obtained. After the bladder has been emptied a measured amount of sterile salt solution is instilled into the bladder, allowed to remain for a few minutes and then removed and measured. If there is any discrepancy in the amount placed in the bladder and that recovered, one immediately suspects the possibility of a rupture in the urethra or in the bladder. If a discrepancy exists, a cystogram and urethrogram are performed. Regardless of this routine procedure, occasionally a rupture of the bladder or of the urethra is missed.

One of our patients, a boy, was in an automobile accident, and sustained a fracture of the pelvis with a marked separation of the symphysis. He was unable to void at the time of entry to the hospital. A catheter was passed into his bladder with ease and urine obtained which contained a very small amount of gross blood. Sterile salt solution injected into the bladder was recovered in the same amount as injected. A cystogram outlined what seemed to be a fairly normal bladder. The bladder was then allowed to empty, and as the catheter was withdrawn a small amount of opaque substance was allowed to run into the urethra. At the end of this examination it was decided that the boy did not have a rupture of the bladder or of the urethra. However, very soon thereafter he developed clinical signs of a ruptured urethra, and the cystograms were reviewed with the roentgenologist. It was at this time that it was first noticed that the bladder shadow in the cystogram was exceptionally high in relation to the symphysis pubis and that there was a small indentation in the side of the bladder in the first cystogram which persisted during the emptying of the bladder. The roentgenologist diagnosed a rupture of the posterior urethra external to the sphincter.

The patient was then operated upon and we found a rupture of the posterior urethra with extravasation of blood around the neck of the bladder which accounted for the indentation seen in the cystogram.

KELLOGG SPEED (Chicago): I have handled quite a large number of such cases, one of the most peculiar of which was that occasioned by a patient sitting on a croquet mallet, balancing himself on the cross bar. A twist of the body fractured the handle of the croquet mallet, causing a long spiral point of the wooded handle to penetrate through the perineum into the urethra.

In the fractures of the pelvis during the War and subsequently, I have handled a large number of gunshot injuries of the urethra and pelvis, and

in over 200 closed or open fractures of the pelvis I have seen urethral involvement in not much over 2 per cent.

Stress of the discussion might very well be laid on the optimism with which the essayist treated his case, because in hospital experience in the large cities there is an enormous mortality from rupture of the urethra, due as has been said, to delayed recognition. Patients may lie for three, four, or five days in the hospital bed without definite knowledge that the urethra is torn or ruptured. The high mortality, of course, is caused by the pressure necrosis from the extravasated urine in the perineal tissues in front of the triangular ligament with absorption and a rapid toxemia. Even wide incision and multiple drainage incisions will fail in many such cases to preserve life, and so a very early recognition is necessary. In routine treatment all fractures of the pelvis should be suspected of caresing ruptures of the urethra and perhaps the first thing the patients should be required to do, if conscious, is to attempt to urinate. If urination cannot be obtained naturally in two hours, they certainly should be catheterized to ascertain whether rupture is present and then suitable surgical measures such as have been shown here must be instituted.

The delayed cases carry statistically a mortality of over 50 per cent.

WILLIAM J. CARSON (closing): I want to thank the speakers for their excellent discussion. As the majority of these cases are not complete ruptures, the treatment is more simplified.

As Hamilton Bailey pointed out, the more simple the treatment the better. I have used the method shown by Dr. Weil and on several occasions, over long distance telephone, have advised surgeons to do the suprapubic cystotomy first and pass a catheter through the prostatic urethra into the torn part of the perineum; second, to make an incision in the perineum over a sound, withdraw the tip of the bladder catheter out of wound, remove the sound, pass a catheter through the urethra and tie the catheters together with heavy silk, then withdraw the suprapubic catheter until the urethral catheter extends into the bladder 2 cm. That will suffice in many cases, but if there is a complete tear and only that splinting is done, a stricture will result and last throughout life.

Extravasation of urine is the most dangerous complication and I feel that Hamilton Bailey has pointed out its important aspect. "You cut your mortality in half by draining through the perineum."

TRANSIENT FALSE MENINGOCELE— A CLINICAL ENTITY*

PRELIMINARY REPORT

EUGENE J. BOZSAN, M.D., F.A.C.S. AND

THOMAS I. BRENNAN, M.D., F.A.C.S.

NEW YORK CITY

THE escape of cerebrospinal fluid under the scalp through a traumatic opening in the skull is known in particular since the publications of Billroth and Marjolin. Since then, this occurrence was observed in a number of instances and a survey of literature made by the authors has yielded over eighty publications bearing directly on this phenomenon, which has been described predominantly under the name of "false meningocele" as contrasted with congenital true meningocele.

FIG. 1. Large collection covered by normal skin.

FIG. 2. Small collection covered by normal skin.

The condition was considered a more or less stationary one and tractable only by operative procedures or repeated aspirations, often followed by fatal meningitis. Its occurrence was believed to be rare, and few authors reported more than a single case or at best a small number of cases of their own.

* From the services of Dr. E. J. Bozsan, Morrisania City Hospital, and Dr. M. Bodenheimer, Hospital for Joint Diseases, New York City.

Observation of a large clinical material of head injuries during the last ten years, however, has convinced the authors that a particular type of false meningocele bearing constant features, occurs rather frequently in children following blunt head injuries.

FIG. 3. Hematoma showing discoloration.

FIG. 4. Hematoma showing discoloration and bruise.

The main characteristic of this type of cerebrospinal fluid collection is that it disappears spontaneously without any treatment and that in its presence a favorable outcome may be predicted even in the face of rather severe status immediately after the accident.

The authors have observed during the last ten years twenty-nine cases. They believe, however, that this escape of spinal fluid occurs more frequently and that cases are overlooked or are erroneously registered as "hematoma of the scalp." This conjecture is corroborated by the survey of literature since papers dealing with the well known benignity of skull fractures in children often report the presence of hematomata in the case histories.

The authors believe that these so-called hematomata themselves are the reason of the relative benignity of the observed cases, as they contain not blood or not only blood, but spinal fluid, and that through this temporary subcutaneous reservoir, the cranial cavity efficiently decompresses itself.

The clinical features of this type of false meningocele which, because it disappears spontaneously, the authors have come to name transient, are as follows:

Immediately or days after a blunt head injury, a small or large swelling appears on the head, covering at times the whole of the cranial vault. The swelling is painless. Children permit the palpation

FIG. 5. Typical *x*-ray picture of false meningocele.

FIG. 6. Typical *x*-ray picture of hematoma.

of it without fear. The covering skin shows no trace whatever of the irritating presence of extravasated blood, edema, bruise or ecchymoses. During its total stay, no discoloration occurs either early or late, blue or yellow. In most csase the swelling shows loose watery fluctuation, like that of a partly filled hot water bag, often permits palpation of the underlying bone and never discloses snowball crepitus. It transilluminates with the pink hue of a hydrocele. A day or so after its appearance, a circular rim appears at the base of it, which leads to the erroneous conclusion of depressed fracture and is often described by the interns as a "crater."

This clinical picture is strikingly different from that of a true hematoma which is painful, surrounded by edematous skin, shows crunching crepitus of coagulated blood, exhibits bruises and ecchymoses and soon becomes discolored, first black-blue and later yellow. Figures 1 to 4 show clearly the different appearance of the two.

This difference is also apparent by *x*-ray. The films taken with soft part technique show that the skin over the false meningocele (Fig. 5) is of uniform thickness over the whole extent of the swelling and it is the same as that of the surrounding skin. Under the skin and

separated from it by a narrow cleft is a smoothly outlined shadow of even density hugging the surface of the skull. All structures, bone, fluid and skin, are clearly separated and their borderlines are not blurred or lost.

FIG. 7. False meningocele appearing five days after accident.

FIG. 8. Same as Figure 7, with total disappearance of collection in seven days.

The *x*-ray picture of a hematoma shows (Fig. 6) in contrast to the above, the skin increasing in thickness from the periphery to the apex of the swelling, spotted with blotches of bloody infiltration and the main mass of hematoma fused with the edematous skin.

Aside from this different clinical appearance, the presence of spinal fluid is indicated by the at times rapid disappearance of the swelling without leaving any trace, and not followed by thickening or fixation of the scalp.

In contrast to this, the hematoma lingers long and fixes the scalp for a considerable time.

No hematoma disappears so quickly and completely as the False Meningoceles illustrated. (Figs. 7–10.)

Against hematoma speaks further the belated appearance of the swelling, at times many days to two weeks after the accident, generally after resumption of more vigorous activity. In one of the cases, the appearance of the collection two days after the accident was preceded by a period of restlessness and drowsiness, indicating increased intracranial pressure which simultaneously disappeared

FIG. 9. Complete false meningocele. (August 29, 1930.)

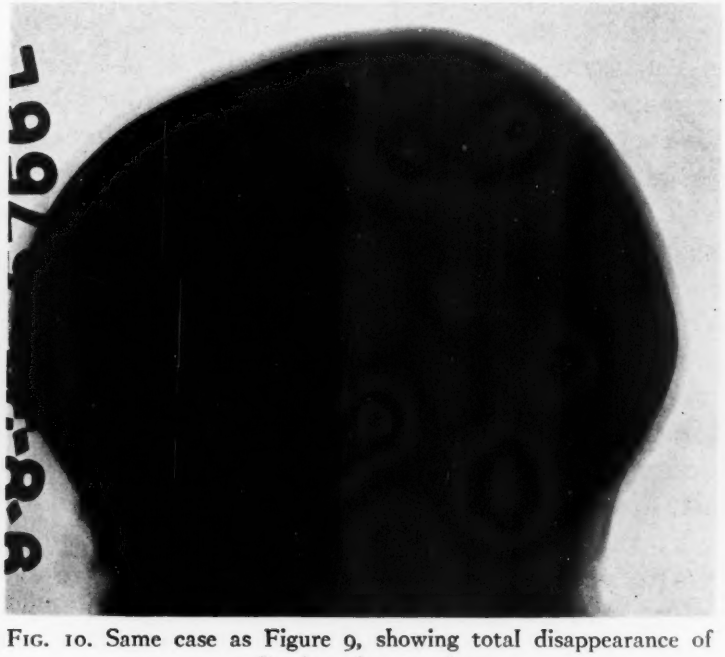

FIG. 10. Same case as Figure 9, showing total disappearance of collection after ten days.

FIG. 11. Typical vertical fracture line.

FIG. 12. Typical horizontal fracture line.

with the appearance of the swelling. In another case, spinal puncture made the swelling disappear, to reappear the next morning.

Circumstantial evidence, as mentioned above, seems to prove

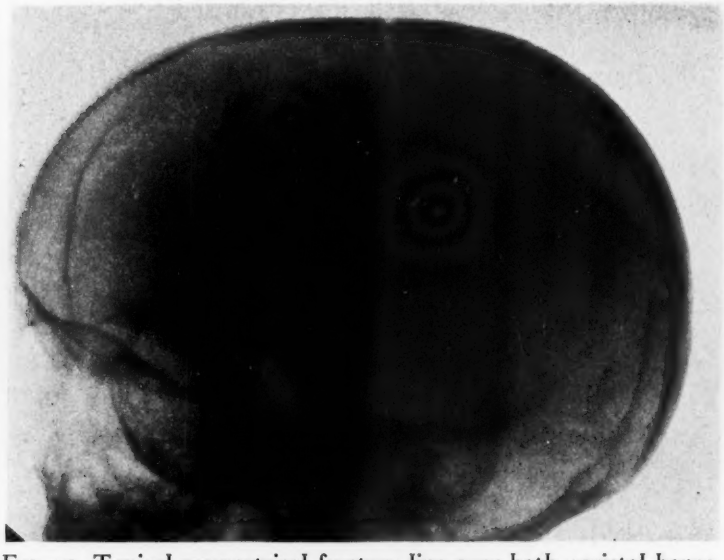

FIG. 13. Typical symmetrical fracture line over both parietal bones.

that these swellings contain mainly spinal fluid even if mixed with blood. The authors are definitely opposed to the practice of *proving* the presence of spinal fluid directly by puncture and aspiration. The literature records too great a number of fatalities after aspirations to make this procedure safely practicable.

Puncture and aspiration, however, were performed in our group of cases four times, always on the basis of erroneous diagnosis of hematoma, and in these cases the presence of spinal fluid was proved. In one case, by two repeated aspirations, a total of 235 c.c. of "bloody serum" was removed, the collection returning after each aspiration to disappear spontaneously later. In two other cases, aspiration also proved the presence of spinal fluid. In the fourth case, aspiration was performed only after an "influenza bacillus-like" organism had caused meningitis. In this case, aspiration produced milky pus without any trace of blood. The autopsy of this the only mortality in the group, showed the communication of the cranial cavity with the collection under the scalp.

Beside the constant clinical features, the mechanism by which this escape of spinal fluid under the scalp is brought about is also identical. It accompanies that type of skull fracture in children called indirect, that is, where the fracture occurs not at the site of the

FIG. 14. Typical complete collection.

FIG. 15. Typical complete collection.

attack of the force, but at a distant place. These fractures are sometimes called fractures by "contrecoup." There seems to be a difference in the use of this latter term among different writers, some using

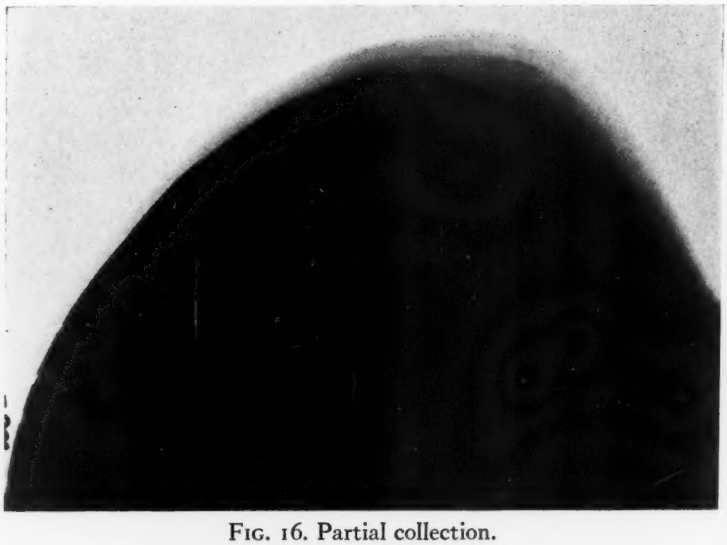

FIG. 16. Partial collection.

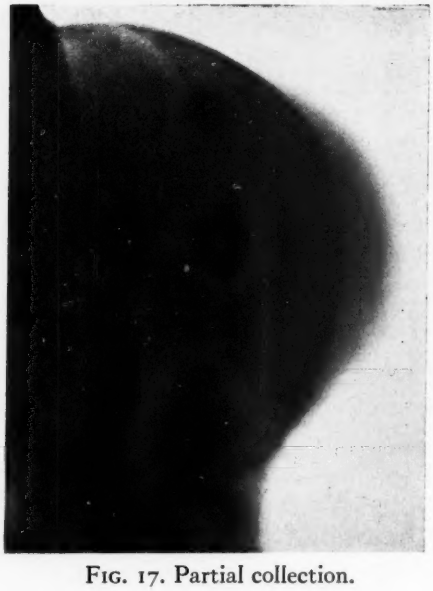

FIG. 17. Partial collection.

it to designate injuries to the brain tissue opposite the point of attack of the force, through hurtling the brain by its momentum or semi-fluid wave against the inner side of the skull at this point. For this reason the term of indirect fracture is chosen.

The mechanism of these fractures is well understood and simple. The elastic skull of a child, compressed by the force of the impact

undergoes a momentary alteration of shape, the maximum of which is located somewhere at the equatorial plane in relation to the point of impact. At this plane of maximum bending, if the force is sufficient,

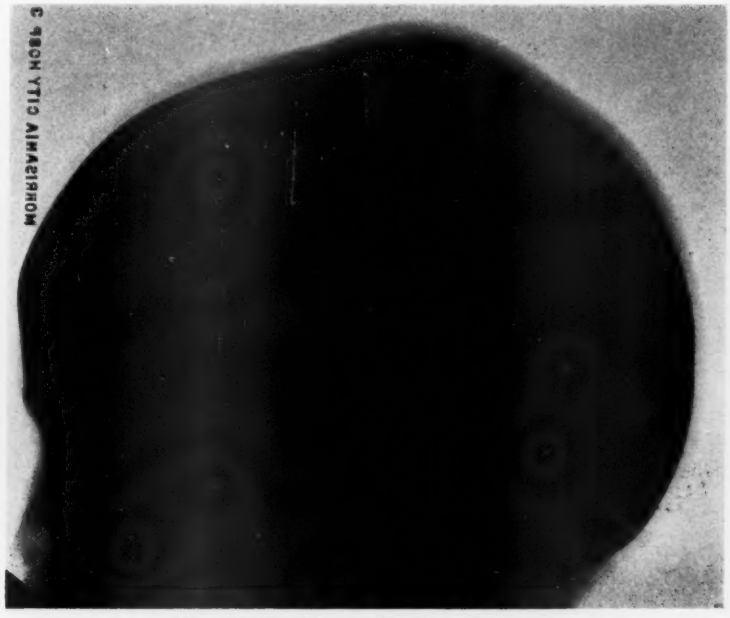

FIG. 18. Smallest collection observed.

a linear fracture will occur. If the infantile skull is compressed in the fronto-occipital direction, this fracture occurs in a line running over the top of the skull in the frontal plane. (Fig. 11.) If the compression occurs from side to side, the fracture line runs in fronto-occipital direction, higher or lower. (Fig. 12.) In the latter case, the fracture line is most of the time continuous, in the former it may be present only over the maximum convexity of the two parietal bones and is interrupted in the middle line. (Fig. 13.) Of course the skull may be compressed in any meridian, the above-mentioned rule remaining still demonstrable but due to various factors, not as manifestly.

It is these indirect linear fractures over which the transient accumulations of spinal fluid occur.

In the child, the bones of the skull lack diploe and are intimately united with the dura. If fracture occurs, the dura will tear. If intracranial pressure increases due to any reason, this may burst the arachnoid and spinal fluid escapes. If the arachnoid remains intact or the fracture is incomplete, the spinal fluid will not escape immediately after the accident, only some time later when the fissure line becomes widened by absorption or the patient assumes more vigorous activities than during the days immediately following the accident.

In these latter cases, the swelling occurs after a shorter or longer period following the accident.

These accumulations of spinal fluid may cover the whole skull.

FIG. 19. Symmetrical appearance of a double collection.

Figures 9, 14 and 15 show three of the four complete cases in this series. Most of the time the collections are smaller. (Figs. 16 and 17.) In Figure 18 the smallest collection observed is illustrated.

In cases of symmetrically located fractures the fluid accumulations will assume a strikingly symmetrical aspect. (Fig. 19.)

These indirect fracture lines seldom run into the base. The elastic alteration of the shape of the vault absorbs most of the force. Occasionally, however, as compression exerts its force over the whole bony sphere of the skull, the fracture line extends to the base or a separate fracture line may correspondingly exist there. From these, some slight bloody infiltration originates. As signs of these supposedly bloody infiltrations, we have observed marked pallor of the face as compared with the hands, indicating irritation of the sympathetic nerves. Ecchymosis of the eyelids, passing palsy of the eye muscles, and double vision, were occasionally observed. In one instance a group of herpes vesicles appeared along the course of the infraorbital branch of the fifth nerve, interpreted as a sign of irritation of this nerve at the base.

The authors have assumed as a justified conclusion that in these accumulations, a constant absorption of spinal fluid takes place, much like the accumulation operatively created in the treatment of hydrocephalus. This in their opinion establishes an efficient decompression, not only by forming a temporary reservoir, but also by

eliminating a quantity of the excess fluid. How fast this absorption is remains a matter of conjecture. Concluding from the at times surprising rapidity of disappearance of these accumulations, the impression of the authors is that the absorption is intensive.

The absorption of the fluid is rapidly followed by the disappearance of the rim. The skull becomes smooth and in two or three days the scalp is again as movable as over the rest of the head. This rim is believed to be new bone and is noticed only around partial collections. In the complete collections this rim is not observed.

With such a large series of cases proceeding to spontaneous absorption without exception, the question arose why so many cases reported in the literature remained permanent. A careful analysis of this latter group led the authors to the opinion that it is the type of trauma that determines the permanent or transient feature.

If false meningocele appears over a gunshot or operative wound or over comminuted fractures due to direct trauma, it tends to be permanent. Due to loss of substance or displacement of fragments, the chances of spontaneous closure are unfavorable. The indirect fractures in children, on the other hand, tend to close as the skull regains its shape after the trauma and they give rise to the transient type just described. To this rule there is an exception, namely, when the mechanism of indirect fractures results in the bursting of a suture line.

SUMMARY AND CONCLUSIONS

The material underlying this report, of which detailed analysis will be given in a later publication, reveals that: The age limit of occurrence of transient spurious meningocele was between 1 and 13 years. One case was observed at the age of 17 and another at 18.

The collection appeared immediately after the accident in seventeen cases, and was belated in twelve cases, one to fourteen days after the accident.

The duration of the collections varied between two and twenty-eight days.

X-ray evidence of underlying fracture was present in twenty-seven cases, absent in two cases.

General condition after the accident was severe in five cases, moderate in ten and mild in fourteen cases.

In four cases, the collection covered the whole vault, in twenty-five cases it was partial.

In two cases the collection was double, symmetrically placed, twenty-seven cases the collections were single.

The authors believe that these passing collections of spinal fluid under the scalp deserve careful attention, and their presence may be considered a favorable circumstance as far as immediate prognosis is concerned.

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DISCUSSION

FRANK H. MAYFIELD (Cincinnati): I would like to congratulate Dr. Bozsan and his co-author on the amount of material they have, and also upon the interesting way that they have presented it. I am in accord with the idea that this is probably a clinical entity. It has a counterpart in Dandy's subdural hydroma which, I think, differs from this lesion only in that it connects with the subdural space through a fracture line. I am in accord with the idea that extravasation of cerebrospinal fluid under the scalp is often a protective decompressing mechanism and acts for the betterment of the patient rather than to his detriment.

Dr. Bozsan's criteria for differentiating between hematoma and hydroma are excellent. I agree that it is unwise to aspirate a cavity, or to aspirate repeatedly cavities which communicate with the subarachnoid space.

However, I consider the name badly chosen, for there is in no sense a herniation of the meninges. It is merely an extravasation of fluid underneath the scalp, and I think it would be better named subgalial hydroma or perhaps extracranial hydroma in deference to Dandy's subdural hydroma.

The delayed appearance of the fluid under the scalp which Dr. Bozsan feels is due to rupture of the arachnoid membrane, I would be inclined to explain on the basis that a clot which has been blocking the fracture line had been absorbed and had permitted the extravasation of fluid. At least, I believe, that is the generally accepted opinion as to what happens when leaks appear through the nose or ear later on.

He referred to the rim which could be palpated about the margin of the swelling as possibly being proliferation of bone. This thing appears within a very few hours after the onset of the swelling, and I think it far more likely that it is either a marginal hematoma about the swelling or a false impression of depression, in that the scalp is thinner, stretching from the fluid under it, rather than a proliferation of bone.

While its frequent spontaneous disappearance would certainly indicate that aspiration of the fluid is rarely if ever necessary, I certainly would not have any great fear of infection from the insertion of a sterile needle through a clean area of scalp. I can see no reason why infection should be

more prevalent in this situation than in any ordinary spinal puncture. I can recall two instances in which I thought aspiration was rather helpful.

A child developed extravasation of subdural fluid after injury, and at the same time had a terrific head injury with bloody spinal fluid. He developed signs of irritative meningitis, which so frequently appears in subarachnoid hemorrhage, and we were able to alleviate it by aspirating the cavity through the scalp.

Another patient came in with a small extravasation of fluid similar to those shown, who also had an infected abrasion on the scalp in the neighborhood. The skin immediately over the swelling was intact and clean, and I aspirated it and applied a pressure bandage to discourage recurrence of the collection. I felt happier about it, because I thought we had reduced the chance of getting an infection into the subgalial collection of fluid. You may disagree with that.

EUGENE J. BOZSAN (closing): The name of the condition I did not choose, and I cannot assume responsibility for it. In going through the literature I found this name used in about eighty or ninety publications. I have adhered to it, not wanting to create a new one.

As far as the delayed occurrence is concerned, I perfectly agree with Dr. Mayfield in attributing importance to the absorption of a clot or widening of the fissure by absorption. I have not reported the statistics, in which it is clear that these cases of delayed appearance constitute a large percentage. This fact I believe is also a factor in the opinion that these collections contain spinal fluid and not blood.

About the rim, I am perfectly willing to retreat convinced though I am that it is newly formed bone, I have not actually seen any; in the one case autopsied I do not recall the report of the examination of the rim. I assumed the formation of the bone in the rim on the analogy with the rim formation in kephalhematomata.

I am opposed to diagnostic aspiration merely because I do not wish to add needlessly even the remote chance of infection.

I omitted to mention one feature. In one of the cases spinal puncture made the swelling disappear, but it reappeared next morning. The very capable resident fortunately made accurate notes of the occurrence.

BRAIN ABSCESS OF TRAUMATIC ORIGIN

JOSEPH E. J. KING, M.D.

NEW YORK CITY

TRAUMATIC abscesses of the brain result from introduction of the infecting organisms by injury, as opposed to the majority of instances in which the abscess is secondary to otitic infections, infections of the accessory nasal sinuses, true osteomyelitis and other diseases of the skull and those of metastatic origin.

In one group of traumatic abscesses, the infection is directly implanted into the brain substance by accidental perforation of the skull with sharp pointed objects, e.g., scissors, knife blades, nails, files, icepicks, etc. The external wound may heal and the accident be considered trivial until an abscess begins to develop, or the external wound may become infected, fail to heal, and the abscess may discharge pus from the wound of entrance. We have seen, on the other hand, two cases of perforation of the brain to a depth of 2 inches through the roof of the orbit by pointed objects without abscess formation or any other apparent permanent damage. The abscess may be secondary to compound comminuted fractures of the skull, usually involving the cranial vault. Meningitis is more likely to occur after compound linear fractures of the base of the skull.

Fragments or spicules of bone, pieces of metal, concrete, hair and dirt, carrying infected material with them, may be driven into the brain substance and an abscess may form around them or in the area from which they were removed. In like manner an abscess may be caused by gunshot wounds. These abscesses usually are completely formed within three to five weeks, are diagnosed and treated with greater ease, and are quite amenable to surgical interference.

In another group, the trauma may be connected more indirectly with abscess formation. Simple linear or comminuted depressed fractures may involve the mastoid, or the accessory nasal sinuses, which already harbor infection. In some instances, an infection of these bony cavities may be induced by the fracture line or lines invading them. In either case, the infection may spread to the brain by any of the known routes associated with the formation of a brain abscess secondary to otitis, mastoiditis, ethmoiditis, frontal sinusitis, etc., namely, by direct extension, retrograde thrombosis and along

the perivascular spaces. At the time the fracture occurs, the dura may be punctured or torn by the margin of a bone fragment. In the absence of compounding externally, infection of the bone fragments of the fracture site through the bony cavity may be delayed. Therefore development of an abscess may not become apparent for quite a length of time.

In some injuries without fracture, the scalp may be badly torn or partly avulsed, with dirt and detritus ground into the outer table of the skull, followed by infection and necrosis of a portion of the skull. The infection may spread to the meninges, produce a localized leptomeningitis, and beneath this area a subcortical abscess may develop.

A compound fracture may possibly or actually be operated upon improperly, the wound may heal and the patient's condition remain good for several weeks or months, only to be followed by formation of an abscess caused by infection retained in the wound of the extradural soft parts. Abscess may be caused by improper maneuvers at operation for mastoiditis or disease of the paranasal sinuses. A probe may be pushed through a dehiscence in the inner table and adherent meninges and thus implant infection directly through the meninges. An abscess may develop in the brain after a procedure which can only be mentioned for condemnation, i.e., exploring the brain through an infected dura, either with a needle, cannula, searcher or knife. As many abscesses may form as there are punctures. At a recent autopsy after removal and fixation and section of the brain, three abscesses were seen in the left temporal lobe following three punctures with a needle done by an otologist through infected dura which had been exposed by removal of the dural plate at a previous operation. Unless the abscess is absolutely localized by ventriculograms—and not on suspicion—exploratory puncture through infected dura is *most strongly condemned.* The lesion producing the ventricular distortion, even in the presence of extradural infection, might be a tumor or cyst. Therefore, in any case, exploratory puncture should be through a clean field. If the dura is carelessly or accidentally torn by a curette during an operation on the mastoid or sinuses, infection may be implanted in the brain substance, but meningeal infection is more likely to ensue.

Foreign bodies—bullets, shell fragments, pieces of helmet, broken-off knife blades, etc.—may be retained in the brain for weeks, months or years without producing undue symptoms. As a result of a blow on the head, or some other cause, the latent infection may flare up and an abscess may develop about the foreign body.

An abscess is likely to follow removal of a foreign body which has been in situ for a long time. In a fairly recent case, a piece of knife blade was removed from the right fronto-parietal region of the brain of a negro man. It had been in the brain for over twenty-eight years and was located by radiographs. He complained only of some weakness of his left hand, for which he was admitted to the hospital. He had no knowledge of being stuck in the head but remembered being "hit on the head and knocked out in a fight over twenty-eight years ago." The knife blade was removed by one of my associates. No evidence of infection existed. A few months later a large abscess, which developed at the site of removal of the blade, was operated on by the author. In his experience, this was the longest interval between the introduction of a foreign body and the formation of an abscess.

Lastly, the brain may be damaged by contrecoup, or a hematoma may be present, and this area may be infected through the blood stream and form an abscess, as in any other part of the body. There may be other types of trauma which serve as a causative factor in the production of a brain abscess, but the more common conditions have been enumerated.

Bacteriology. Where the infection has been carried directly into the brain, the *Staphylococcus aureus* is most often found in the smear and culture. However, any or mixed pus-producing organisms, may be found.

Pathology. Traumatic abscesses when caused by direct implantation of the infection may be small or large. They may be fairly superficial, shaped like a shallow salt cellar or about 2 or 2½ inches deep and elongated like an old-fashioned moneybag. They may also be irregular in shape. They are usually single; some observers consider this to be the case in about 90 per cent of the instances. In the present series, all were single, although one large abscess showed two extensions or pockets on inspection, one rather large, and the other small.

The abscess may become well-formed and well encapsulated early, i.e., within three weeks. A very firm, fibrous wall is usually present, especially near the periphery, due to the presence of a large amount of connective tissue derived from the dura and other tissues. It may, or may not discharge pus through the wound of entrance. The pus may have a very foul, putrid odor, or there may be but little odor. It is thinner and more watery in consistency, also paler than that contained in a nondischarging abscess. In one instance, gas

bubbled from the tract and appeared on the *x*-ray film to be at the top of the abscess.

In drainage tract abscesses caused by gunshot wounds, and where a tube has been in position for a considerable length of time, a wall about ¼ inch thick in most of its extent forms about the tube. After removal of the tube and healing of the external wound, the partially collapsed cavity may remain quiescent for quite a while. The latent infection may be relighted by a blow on the head or some other cause, and the abscess may suddenly rupture into the lateral ventricle.

Such an instance was observed in the army where a soldier sustained a gunshot wound of the right frontal lobe. An abscess developed in the tract and was drained for several weeks by a rubber tube. The tract ran obliquely backward and outward from a point near the middle of the forehead for a distance of about 3 inches. After removal of the tube, the wound healed kindly and the patient made what was considered a good recovery. He was quite intelligent, had a good working knowledge of airplanes, and demonstrated the mechanics of airplane repairs and construction to other patients in the occupational therapy department.

One night, several months after the healing of the wound and his return to work as instructor, he was in a public house, drank a bit of wine and became somewhat unruly and boisterous. An M.P. was called and, in the attempt to quiet the man, tapped him lightly on the head with a billy. This light blow served the purpose of subduing the man, but did not render him unconscious. He was escorted to his barracks, went to sleep, had a good night's rest and, for the time being, was none the worse for the spree. The following morning at about 10 o'clock, he was sitting at a table playing pinochle with his mates, when he made a sudden outcry, threw up his hands, fell back unconscious on the bed and never recovered consciousness.

On lumbar puncture, milky cerebrospinal fluid was obtained under marked pressure, loaded with pus cells and organisms. The patient died thirty-six hours after the episode. When the brain was sectioned, the long, thick-walled tract was found to be almost completely collapsed, with a narrow space between the two walls containing thick, inspissated pus, the consistency and color of peanut butter. Further section showed a thin portion of the wall through which a perforation into the ventricle occurred.

Many discharging brain fistulae were observed in old infected gunshot wounds of the head, some discharging pus copiously for many months. After removal of a small piece of dead bone fragment with a fenestrated curette, and institution of proper treatment, the fistulae usually closed.

When the abscess is secondary to traumatic involvement and infection of the mastoid and accessory nasal sinuses, it has the

characteristics of brain abscesses complicating primary disease of these structures. In shape they are usually ovoid or spherical. The various stages are edema, softening of the brain, suppurative encephalitis with necrosis, free pus formation and encapsulation. The time required is from three to five weeks after the initial spread of infection to the brain substance. The wall or "capsule" is from 2 to 4 mm. in thickness.

Signs, Symptoms and Diagnosis. If there is a discharging sinus, the diagnosis is fairly evident. If a small tube is introduced into the tract and a large amount of pus is discharged through the tube, the diagnosis is well established. *X*-ray films may show the cavity partly filled with gas and a fluid level. These patients are not very ill, once the intermittent or continuous discharge of pus takes place.

On the other hand, if the abscess is intact, it exhibits the same signs and symptoms as abscesses of nontraumatic origin—pain in the head, tenderness on percussion, nausea and vomiting, prostration, loss of appetite and weight, slow cerebration, monoparesis or hemiparesis or hemiplegia if the motor area is involved directly by the edema, motor asphasia (if the area of Broca is directly involved or if the abscess is large and is in the dominant frontal lobe), drowsiness and stupor. The deep reflexes are usually increased, especially on the contralateral side, with decrease of the corresponding abdominal reflexes.

Involvement of the cranial nerves will depend upon the location of the abscess. Fundus changes are likewise similar to those in other abscesses. Papilledema is not observed in the early stages, but may be present later. There is engorgement of the retinal veins and there may be hemorrhages. Visual field defects, if they exist, will vary with the location of the abscess.

There is usually a leucocytosis, the count being between 9,000 and 16,000. The cerebrospinal fluid may show a normal cell count, or it may be increased. Manometric readings show increase in pressure.

The diagnosis, as a rule, is made earlier in traumatic than in nontraumatic cases, since the existing head trauma will more often and more promptly arouse suspicion of the existence of a subcortical lesion. The differential diagnosis between abscess and meningitis, suppurative leptomeningitis, subdural and extradural pus pockets, and edema, should be made if possible. The abscess is also more favorable for localization. Should attempts to make the diagnosis and localization fail, one should resort to verticulography, and not encephalography. Displacement and distortion of the ventricular system will almost always indicate the location of the abscess.

Treatment. Prophylactic measures, in general, deal with prompt removal if possible, of the extracranial or cranial source of infection to which the brain abscess may be secondary. Compound fractures of the skull should be properly and completely operated upon, preferably in the first eight or ten hours. It is remarkable, even in this time, how many cases of head wounds are badly cared for. Scalp lacerations are carelessly sutured tightly over infected material. I maintain that every laceration of the scalp should be closed under good light in the operating room and not haphazardly in a dressing room. Some observers believe that the infection of the brain substance takes place simultaneously with the onset of infection of the mastoid and sinuses. This may be true in some cases, but the delayed riddance of infection in these structures is responsible, without question, for many more, and one must admit that, in some instances the direct cause of the infection spreading to the brain is due in a large measure to *delayed* operation, *careless* operation, or *inadequate* operation for infection of the traumatized mastoid or accessory nasal sinuses.

When an abscess begins to develop, provided it is not metastatic, supportive measures to help maintain the best possible general condition of the patient until walling-off of the process has been accomplished, are of primary importance. This walling-off period is from about two and one-half to four weeks in duration. The increased and sometimes high intracranial pressure should be reduced by means of intravenous sucrose solution, 100 c.c. of 50 per cent solution every four hours or less, frequent saline laxatives and cathartics, enema or colonic irrigations, elevated position of the head, and careful lumbar punctures when indicated.

Lumbar punctures for decompressive effect should not be done when the abscess is in the cerebellar lobe. Ventricular puncture through the anterior horn is preferred. Headaches and pains in the head are almost immediately relieved by tapping the ventricle. Cerebration improves and the patient, who may otherwise have been in deep stupor, usually becomes quite alert. Repeated ventricular punctures through the anterior burr hole may be necessary both before and after operation for cerebellar abscess. The anterior position of the burr hole mitigates against infection from the operative wound after the abscess has been drained, and the site is also convenient for tapping.

Operation should be done after a well formed wall has developed. The period required may be no longer than 2½ weeks. Otherwise, the approved time is from twenty-one to thirty days. In a majority of

cases seen by the neurologic surgeon, the abscess wall has already become well established, and no delay of the operation is necessary. In fact, a few patients may be so ill that the operation may have to be done as an emergency, but this situation is rare due to increased knowledge regarding dehydration and decompressive measures.

Until the patient comes to operation, at the hands of a capable surgeon, experienced with the conditions under consideration, it would be much better if the inquisitive meddling searcher-for-an-abscess could adopt an absolute "hands off" operative policy. If such an attitude existed, one would not so often be called upon to attempt to save the life of an individual whose condition is not unlike that of an inexperienced swimmer from whom one has taken a lifebelt. I have for some time held the opinion that one should not boldly plunge in, smugly relate afterwards that he "struck pus" (a favorite expression), watch one complication after another develop until the situation is well out of hand, and then hurriedly and sometimes patronizingly dump the remnants of a case into the lap of a colleague.

Several procedures, with modifications, have been advised by various writers and observers. The main objectives and desires should be the preservation of the life of the patient, removal of the pus with subsidence of brain edema and healing of the wound with recovery of the patient and return to his normal life.

The aim at operation is the *prevention* of meningitis, rupture into the ventricle, repetition of infection of the brain, multiple operations for the same single lesion, paralysis, convulsions and death. It is very doubtful if any described operative procedure would meet all of these requirements and would result in 100 per cent cures.

In cerebral abscesses I have employed for several years an operation, the chief principles of which were advocated in 1923. On several occasions I have published a description of this method, and it is not necessary to repeat it here. Suffice it to say that an opening is made in the skull, dura, brain cortex and abscess to provide a *direct* approach, entrance and avenue into the abscess cavity. One can get rid of the pus once and for all, enlarge the opening sufficiently to allow thorough inspection of the interior of the abscess cavity, see whether openings into secondary pockets or extensions exist, and, if they do, deal with them in such manner that they become a part of the main cavity and do not remain like a cellar or attic stored with dynamite. After a complete survey has been made, the abscess cavity is slowly effaced, leaving no trace, by controlled gradual elevation of the floor of the abscess *up to*, but not *beyond* the level of

the skull. One might ask what becomes of the cavity, and this question can be answered by stating that it simply *disappears*. It does not remain in the cranial cavity. It forms a part of the scar on the brain surface, granulates over, becomes covered with epithelium, like any scar, and the area heals.

Scalp plastic is usually performed about six months or one year later. The scar is excised and normal scalp edges are brought together.

REPORT OF CASES

In sixty cases of brain abscess which have come under the observation of the author since 1920, only seven were of traumatic origin. Three cases have already been reported more or less in detail, and four more will be reported in this paper.

CASE 1. *F. R., male, white, 56 years old, a barber, was admitted to the Jersey City Medical Center, February 2, 1935. He had a brain abscess in the left postfrontal region, resulting from the introduction of a penknife into the brain through an operative cranial defect made ten years previously. Operation was followed by recovery.*

The patient was picked up in the street by the hospital ambulance. He was in a comatose condition and had a deep laceration of the scalp. The history was later obtained piecemeal from relatives and from the patient during his hospitalization. Early in the morning on the day of admission he had awakened a member of the family to ask the time. About three hours later the family arose and found that the patient had left. On the bathroom and bedroom rugs there was blood, and about half a cupful in a pan under the bed. He was not heard of until notification of the hospitalization was received. It was later learned from the patient that he had thrust a "penknife" down "to the hilt" into his brain through an old skull defect made by the elevation of a skull fracture ten years previously. During several months prior to this episode, he had had periods of mental disturbance during which he felt that someone was "after him," seeking his life. Associated with this there was a vague history of abdominal pain. At these times the operative site would "itch," and it was while scratching this area that he introduced the penknife. Until the onset of this mental disturbance he was perfectly well and able to work at his trade as a barber. The patient was admitted to the hospital about four hours after he was known to have been at home.

Past History. An appendectomy had been done in 1918. In 1923, while riding a motorcycle, he sustained a head injury which rendered him unconscious for an undetermined period of time. He was taken to a hospital in Norwich, Connecticut, and was operated on immediately.

Physical Examination. The patient's temperature was 98, his pulse 90, respirations 20, blood pressure 135/80. He was an elderly appearing man in a comatose condition and had frequent convulsive seizures of the entire

body. There was a depressed bloody area in the left post-frontal region under which there was definite absence of bone.

The patient was comatose, his pupils were equal and reacted sluggishly to light. The fundi were normal, as were other cranials, motor power, and sensory. The reflexes were equal and hyperactive. A left equivocal plantar response was noted.

Laboratory examination showed the urine normal, the white blood count 10,850, and the red count 4,625,000.

On radiographic examination, there was a skull defect about 1¼ inches long and about ⅞ inch wide in the left postfrontal area, the longest diameter parallel to the anteroposterior diameter of the skull. This had the appearance of an old operative defect for compound comminuted fracture of the skull.

Course in Hospital. For the first six days the patient's general condition remained about the same except that the convulsions subsided. He had a definite "psychosis" in that he thought someone was coming to kill him. He was incontinent of urine at times. His temperature ranged from 99 to 100, and the pulse averaged about 72, with a range of 60 to 90. On about the sixth day there was evidence of infection in the scalp wound.

On the eighteenth day of hospitalization the man became quiet with fixed pupils and weak pulse of 50 or 60, and blood pressure 70/50. A scab was removed from the scalp wound, allowing a large quantity of foul pus to escape. The scalp lesion was then widened with scissors and explored. There was no evidence of a scalp abscess, but a sinus tract leading toward the brain substance was discovered. Culture from this pus was reported as streptococcus.

On the twenty-fourth day the pulse leveled off at a high of 70, and thereafter ranged between 55 and 70 until operation on the thirtieth day of hospitalization, at which time there was definite evidence of a brain abscess and no contraindication for delaying operation.

Operation for brain abscess was done March 4, 1935. When the dressing was removed in the operating room, thick yellow foul-smelling pus escaped from the sinus lying in the middle of the scalp wound. A crucial incision was made over the previously described bony defect centering over the discharging sinus. The cortex was exposed and was seen to be markedly fibrous, with considerable edema. It was firm in consistency. The sinus was easily visualized. Its opening was gradually enlarged by incising the tissue about it, which produced a sudden gush of a large amount of pus. An opening about 1¼ inches in diameter was made into the cavity, so that when the pus was removed by suction and thoroughly washed out with saline, the cavity could be inspected. It is estimated that this cavity contained 2 to 3 ounces of pus. The lateral walls collapsed with remarkable rapidity following evacuation, so that introduction of proper drainage material was impossible. A spinal puncture was done with removal of 40 to 45 c.c. of clear cerebrospinal fluid, an amount sufficient to cause the cavity of the

abscess to open widely and allow proper inspection. It appeared somewhat like a cylindrical tract about 2½ inches deep and about 1 inch or more in diameter which led directly downward, with possibly slight deviation forward. Drainage of such a cavity presented a difficult problem, since it was believed that this abscess could hardly herniate from the depths to the surface. Therefore, two strips of iodoform gauze were placed down to the bottom with the intention of leaving these in place for about six days and controlling the intraventricular pressure by lumbar punctures, so that the base might become more superficial, while the vertical walls were held apart. Fluffed iodoform gauze was loosely stuffed in the outer wound and a copious dressing was applied. The postoperative condition was good.

Postoperative Course. On the second day after operation the patient was more mentally alert, had no complaints, and the maximum temperature was 99.8. Thirty c.c. of clear cerebrospinal fluid was removed, and the outer dressing changed. Spinal taps were done every two days, 15 to 30 c.c. being removed at each tapping.

On the ninth postoperative day the first complete postoperative dressing was done. All the original iodoform gauze was removed by loosening with hydrogen peroxide. The cavity was clean and the walls were covered with healthy appearing granulation tissue. The walls were firmly resistant to pressure, but the cavity remained about 2¼ to 2½ inches deep. A spinal tap was done to open it for better inspection. A thin rubber perforated bag was inserted and was mildly packed with strips of iodoform gauze and a wet azochloramid gauze dressing applied. The general condition remained good, without vomiting, headache, or elevation of temperature above 100. It was deemed advisable to decrease the number of spinal taps, keep the patient in a semi-sitting position, with catharsis for intraventricular pressure control. The patient continued to improve.

By the eighteenth day the temperature remained essentially normal, and by the thirty-eighth postoperative day the cavity had gradually become smaller, being about ½ inch deep. Temperature, pulse and respiration had remained satisfactory, and the general condition had improved steadily. On the thirty-eighth day he mentioned that someone was "after him" again; he seemed rather discouraged and wanted to go home. He continued to have delusions of persecution. On the forty-fourth day postoperative, the cavity was practically obliterated, and on the 64th day, May 5, 1935, he was discharged. The operative site had healed, but he continued to have delusions of persecution and intermittent moody spells with paranoid trend. He was sent to an institution and is there at the present time.

CASE II. *G. C. Male, white, 7 years old, was admitted to Bellevue Hospital July 8, 1937. He had a brain abscess of the right frontal lobe, resulting from a compound comminuted fracture of the skull. Operation resulted in recovery.*

The patient had sustained a compound comminuted fracture of the right frontal bone on May 12, 1937, two months before this admission, pro-

duced by the sharp edge of a car door handle striking his head. He was unconscious for a short time. The wound was treated at another hospital where it was reported that a piece of bone was removed from the laceration, with debridement of the skin, and tight closure, without drainage. He had remained in this hospital three weeks and four days. It was said the wound healed without infection, and the temperature did not rise above 101. He was discharged to his home, apparently without clinical evidence of further complications. While at home he became irritable and was sent to Seaside Hospital because of "fits of anger." At Seaside he showed personality changes, became increasingly irritable, disinterested in his surroundings, and complained occasionally of right frontal headache which was associated with a slow pulse, as low as 46 on occasions, with slight elevation of temperature, nausea and vomiting two or three days prior to admission to Bellevue Hospital.

Past History. The patient had always stuttered. He had had chickenpox at 4 years, was vaccinated at 1½ years. His health in general was good.

Physical Examination. During the day and a half before operation, the pulse averaged 70 (55–95), the temperature averaged 99.2 (98.6–100), and respirations 20. Weight was 39¾ lbs.

The child was well developed, coöperative and alert, but showed a disinclination to play with other children. There was a well healed scar over the right frontal region just below the hairline, extending down towards the frontal sinus area, beneath which was definite inequality of continuity of bone.

The speech was stuttering, but not aphasic. The right pupil was larger than left and did not react to light so well as the left. A slight right facial weakness appeared peripheral in type. The hearing was suggestively diminished on right. There was definite papilledema of about 1 or 2 diopters, equal on both sides, with engorgement of veins, more marked on the right. Other cranials were normal. There was no discernible loss of motor power. Sensation was intact. Reflexes: left biceps and left knee jerks were greater than the right; the abdominals were present, equal and active; the plantars were flexor, although the left seemed less frankly so. No skull tenderness, and no stiffness of the neck were observed. Coördination was normal.

Laboratory examination showed W.B.C. 9,000, with polys 72 per cent, lymphocytes 18, monocytes 10. The sedimentation rate was 17 in thirty minutes, 21 in sixty minutes. Urine was normal and Wassermann negative.

At operation on July 10, 1937, under avertin, local and nitrous oxide and oxygen anesthesia, the old scar which was just beneath the hairline on the lateral side of the frontal bone, extending down to within ½ inch of the eyebrow, was excised. A crucial incision was made and the scalp flaps were held back with self-retaining retractors, exposing viable loosely attached fragments of bone beneath the scar. These were removed with a blunt periosteal elevator. The frontal sinus was not involved and therefore was not entered. The dura was absent in an area directly beneath the bony

fragments, but intact at the edges of the defect. A nick was made in the intact thickened dura, and with a blunt brain cannula, the abscess wall was encountered about 1½ cm. beneath the surface, more toward the midline than directly beneath the fragments. The bony defect was enlarged with rongeurs to about the size of a silver dollar. The overlying cortex was removed by suction, revealing the abscess wall. Three narrow strips of iodoform gauze were placed over the edges of the dura and bone to wall off the cortical surface and meninges.

The presenting abscess was then aspirated through a cannula, thick yellow pus being obtained. The presenting portion of the abscess wall was removed, and about 40 c.c. of pus evacuated by suction. A spinal tap was done with removal of 35 c.c. of clear fluid. This allowed the partially collapsed abscess cavity to dilate and permitted inspection of the cavity. The walls were about 3 mm. thick, and no extensions or secondary pockets existed. An iodoform gauze "handkerchief" was placed in the cavity and several soft strips of iodoform gauze were packed into this according to the method advocated.

Culture of the pus from the abscess was reported to be aerobic *Staphylococcus aureus*. No anaerobic organisms were found.

Postoperative Course. The first dressing was done on the second day postoperative, when the temperature was 99, the pulse 80. The general condition was excellent. The patient was singing, drawing pictures, and playing with toys all day. This status continued until the fifth day postoperative, at which time during my absence, the child began to show signs of increased intracranial pressure which was not controlled by spinal taps, catharsis and position. Too great herniation of the abscess floor was allowed, and upon my return on the twelfth day postoperative, hernia cerebri about the size of a lemon was present with complete eversion of the abscess cavity and a mechanical ptosis of the right eyelid by pressure.

With the advent of the hernia, the temperature ranged from 100 to 101. The treatment now became the treatment for the hernia cerebri, i.e., spinal taps, position, catharsis, a protective dressing with perforated strips of adhesive and pressure applied as indicated at each dressing and dakinization.

On the twentieth day postoperative the hernia was smaller, but was being irritated by trauma due to the fact that the patient turned to the right, the same side as that of the hernia, to watch visitors at the door. When he was moved to the other side of the room, the irritation quickly subsided.

The last spinal tap required was on the twenty-eighth day after operation. On the thirty-second day perforated adhesive was applied over the now small hernia to assure more equal and constant pressure and to hasten epithelization. On the thirty-sixth day a compression dressing was applied. By the forty-eighth day the hernia had completely subsided and only a dimple remained at the site of the abscess floor. He was up and about six days later and on the sixtieth day arrangements were made for him to

attend school in the hospital while awaiting the time for a scalp plastic. It was not deemed advisable to discharge the child to his home because of conditions there and the possibility of trauma.

On January 14, 1938, seven months postoperative, the scalp plastic was performed. It healed kindly. An aluminum leather helmet was obtained for the patient for the protection of the pulsating defect, and on February 16, 1938 he was discharged to his home. When last seen he was in good health, attending school, and doing his school work in a satisfactory manner.

CASE III. *S. W., male, colored, 52 years old, a laborer, was admitted to the neurological and neurosurgical service of Bellevue Hospital November 3, 1937. He was discharged November 29 and readmitted February 12, 1938. He had a right parietofrontotemporal abscess, traumatic in origin, secondary to a knife blade removal on his first admission. It had been imbedded in the brain for more than twenty-eight years. Operation was done three months and four days after removal of the knife blade and recovery resulted.*

Four or five months prior to admission on November 3, 1937 the patient had the first of a series of left-sided Jacksonian seizures involving the face and arm without loss of consciousness and usually without convulsive movements of the leg. The exact frequency and duration of the attacks could not be ascertained. The patient's family noted lapses of memory and some mental confusion. Four weeks prior to the above time the convulsions became more frequent, and the movements of the left arm and face were almost "constant," although there was loss of consciousness. On his admission to the hospital the symptoms became less pronounced and headache less severe, and he became clearer mentally.

Past History. There was a long history of inadequately treated lues, numerous undetailed minor head injuries. The patient stated that his scalp was slashed with a knife thirty years before in a fight, that he was knocked down and did not know that he was stuck in the head with a knife. Frequent alcoholic bouts figured in the history.

Physical Examination. The patient was well developed and well nourished. His blood pressure was 122/80, temperature 98.6, pulse averaged 70, respirations 18.

The pupils were equal and reacted well, the fundi normal. Left facial weakness was noted, both voluntary and mimetic. The left corneal reflex was diminished, but there was no hemianopsia. Slight motor weakness of the left face, arm and left leg was observed, but this was not pronounced in the leg. Sensory examination showed extreme loss of position sense in the left hand with complete astereognosis and tabetic pseudoathetosis. There was diminution of all forms of sensation over the entire left half of the body. All tendon jerks were present, greater on the left side. The left abdominals were diminished and the plantars both flexor.

The urine and blood cytology were normal, the blood Wassermann doubtful. Spinal fluid pressure was 100 mm. water. The fluid was clear,

with ten monocytes and a total protein of 40. The Pardy was negative and the Wassermann negative. Colloidal gold 0011100000.

X-ray examination revealed a "saw-toothed" knife blade in the right parietal bone just above the temporoparietal suture, extending down into the substance of the brain for about 2½ inches.

Operation for the removal of the knife blade was done November 15, 1937 under local anesthesia. The butt could be felt when the head was shaved. A 2 inch incision was made over this area. A burr hole was made and a circle of bone rongeured out, leaving a defect the size of a half dollar. The knife blade was intact in the piece of bone. The blade was removed from the dura and brain easily without opening the dura. A small amount of yellow fluid escaped after removal of the blade. Culture of this fluid was negative. The dura pulsated. The area was cauterized and closed without drainage. There was no evidence of pus.

The postoperative course was uneventful. The headache disappeared and motor power improved rapidly, as did the astereognosis and difference in reflexes. On discharge November 29 there was no disturbance in sensory findings, and it was felt that the patient was cured.

He was not heard of again until February 18, 1938 when another service in Bellevue Hospital asked for a consultation. The patient at this time was almost moribund and had been brought into the emergency room in profound stupor with decubitous ulcers over the dependent portions of the body. No history could be obtained except that his wife stated he had been "too sick to come to the hospital for a month."

Physical examination revealed a markedly emaciated stuporous colored man, reacting but slightly to very painful stimuli, with large dirty decubitous ulcers over the sacrum, buttocks, both heels and right scapular area. The patient was incontinent of urine and feces. Temperature averaged 99.6, pulse 100 to 120, blood pressure 120/90.

Neurologic Examination. The neck was definitely stiff and the Kernig positive. Moderate bulging was present at the previous operative site in the skull. The head was held to the right with eyes fixed to the right side. The right pupil was larger than left and both pupils reacted sluggishly to light. The fundi were normal except for engorgement of veins on the right. There was definite central facial weakness on the left. Other cranials were normal as could be tested, except for suggestive complete left fifth nerve paralysis to sensation. Flaccid paralysis of the left arm and paresis of the left leg were recorded. Abdominal reflexes were present on the right, absent on the left. The deep reflexes were diminished on the left. The plantars: flexor on the right, equivocal on the left.

The white blood count was 9500.

Operation for a brain abscess secondary to removal of foreign body, was done February 19, 1938 at 2:30 A.M. A crucial incision was made over the previous bony defect. The scar tissue underlying was removed, exposing the bony edges which contained bone wax which had been used

to stop bleeding at the previous operation for removal of the knife blade. The defect was enlarged to assure the removal of all foreign material. The dural scar was excised and a blunt brain cannula inserted. At about 8 mm. the typical resistance of a brain abscess was encountered. The overlying brain cortex was removed with suction, exposing the presenting tip of the abscess, which was typically brownish red in color. The presenting portion of the abscess was removed and the cavity was inspected. About 2½ ounces of greenish yellow thick pus were evacuated from the abscess, with thick inspissated pus along the walls being removed with pledgets of cotton and suction. Two extensions or secondary pockets were connected with the main abscess cavity. These were clearly visible after all pus had been removed, one anterior and one postero-inferior. The more posterior extension was globular in shape, about the size of a hickory nut and communicated with the main cavity through an opening about the size of the end of a cigarette. The anterior one was smaller. It was possible to dilate their respective openings.

The usual "handkerchief" of iodoform gauze was inserted into the larger original cavity, with perforations made in it to correspond to the openings into the secondary pocket. Through these openings, smaller pieces of iodoform gauze were placed in order to provide adequate drainage and to afford opportunity for subsequent treatment with clear visualization. Strips of iodoform gauze were packed snugly inside the "handkerchief" and the usual copious dressing was applied. The patient became alert at the end of the procedure and seemed to be mentally clear, but was very weak.

Culture of the pus from the abscess showed Gram-positive intra- and extracellular diplococci and *Staphylococcus aureus.*

Postoperative Course. A transfusion of 450 c.c. of citrated blood was given on the second day. Dressings were done daily with spinal taps as indicated. By the fifth day postoperative the mental status was normal, the hemiparesis was definitely improved, and the temperature was about normal. The maximum temperature was 101°F., the day on which the initial packing was removed. On the sixth day postoperative the entire initial packing was removed, and at this time the secondary anterior abscess was obliterated and the posterior pocket was becoming much smaller. The communication with the posterior pocket was gradually dilated with forceps and three gauze packings were then inserted to allow the cavity to become still smaller. This took place rapidly.

An uneventful recovery followed. The bedsores rapidly healed. The patient was sitting up in a wheel chair on the twenty-eighth postoperative day. His weight, which at the time of operation was about 100 pounds, rose to 113 pounds. At this time there was only a small dimple in the center of a granulating area about ⅝ inch in diameter. On the sixty-fourth day there remained slight weakness of the left upper extremity, but this did not prevent good use of the hand. Gait was normal, and but slight difference

in reflexes remained. The patient weighed 138 pounds at this time. He continued to improve and on the day of his discharge, June 13, 1938, he weighed 157 pounds. When last seen he was in good health. A scalp plastic, under local anesthesia, is to be done.

CASE IV. *S. M., male, white, 18 years old, was admitted to Jersey City Medical Center August 26, 1937 and remained until September, 5, 1937. He was readmitted September 13, 1937, and discharged November 23, 1937. A brain abscess, traumatic, in the right temporal region had followed a puncture wound in this area by sharp pointed scissors. Operation resulted in recovery.*

The patient was first seen in the emergency room at the Jersey City Medical Center on August 27, 1937 at which time he presented a laceration of the scalp 1½ inches long over the right ear produced by another person throwing a pair of scissors at him. The laceration was dressed and he was sent home. Four days later he returned to the hospital having stayed in bed at home in the interval, because of pain in his head. The lacerated area had become very painful and was associated with some dizziness.

Past history was irrelevant.

Examination revealed a well developed boy, who was "not very cooperative"; his face was flushed, and he appeared acutely ill. There was a localized area of acute tenderness and swelling over the laceration above the right ear. This swelling was fluctuant and was diagnosed as an infected hematoma of the scalp. The Wassermann was negative.

On admission to the hospital the fluctuating area was incised, drained and packed with plain gauze. Temperature was 100, pulse 68, and respiration 22. About 20 c.c. of foul smelling blood was evacuated but was not cultured. A wet dressing was applied. Antitetanic serum was not given. Daily wet aluminum acetate dressings were applied.

On August 28, 1937, two days after admission, there was a foul-smelling discharge on the dressing, and the patient complained of headache and photophobia with pain to slight pressure over the right eyeball. Temperature fluctuated for the first four days between 98.6 and 101, with a pulse between 65 and 88. By the fifth day the temperature was about normal to 99, with pulse of 72. The patient was discharged September 5, 1937 was a healed laceration.

He felt well for two days, but then developed frontal headache. A local medical man was consulted and reopened the laceration, obtaining pus. Two days following this the patient was nauseated, vomited five or six times, and had a general feeling of malaise. He improved during the next few days and was well until September 12, at which time headache returned, accompanied by malaise, nausea, vomiting and mild photophobia. He was readmitted to the hospital September 13, one week following his discharge from the hospital and twenty-two days after his accident.

At this time his temperature was 99.4, pulse 70, respiration 20. He was acutely ill and showed a definite mental change, being irritable, mildly uncoöperative, emotionally unstable and apprehensive. The face was

flushed. The laceration over the right ear was open ½ inch and was draining foul-smelling thick yellow pus. There was a fluctuant area antero-inferiorly to the laceration, which was tender, red and warm. General physical examination was otherwise negative.

The patient was moderately stuporous. His neck was not stiff. The pupils were round, regular and equal, reacting to light and accommodation. Definite photophobia was present, more marked on the right. The fundi were within physiologic limits with haziness of nasal margins of disc. The patient's jaw deviated to the right because of pain in the temporal region. Other cranials were normal. The deep tendon reflexes were present and equal, the knee jerks hyperactive, the ankle jerks were rather sluggish. The abdominals and cremasterics were present, equal and active. Plantar responses were flexor. Astereognosis was not noted.

The white blood cells numbered 13,000; 74 per cent polys. Spinal fluid was clear, with a pressure of 180 mm. of water. Cell count showed 10 lymphocytes.

On September 16, 1937 the laceration had about stopped draining. The patient was operated on and an area of necrotic bone about the size of a ten cent piece was found beneath the laceration in the temporal bone. This was enlarged by means of a rongeur, revealing a small rent in the dura underlying it. The dural opening was enlarged and an abscess cavity opened into it. Foul-smelling thick yellow pus was evacuated and one Dakin tube inserted in the cavity. The wound was left wide open and packed loosely with iodoform gauze with wet Dakin dressing.

Postoperative Course. Following this procedure the temperature rose gradually to 101 on the third postoperative day. The general condition improved somewhat for three days. There was gradual diminution in the amount of drainage and the patient again became stuporous, at which time there was *no drainage* from the abscess.

I was asked to see the patient on September 21, 1937 and operation was done the same day, five days after the operation in which tubal drainage was employed. The area was dirty. There was a small crucial incision with flaps sutured together and a small Dakin tube protruding. The brain cortex had herniated to an elevation of about ¾ inch through the 1 inch cranial defect. Through this the tube protruded like a catheter from the cervix.

While the opening in the skull and dura were being enlarged to about the size of a fifty cent piece, a lumbar puncture needle was being inserted. The fluid was clear and colorless. After about 15 c.c. had been removed the brain hernia became softer, and the opening into the abscess larger. Thick yellow pus began to flow out. After the opening into the abscess was spread (firm adhesions had already formed between the cortex and meninges about the hernia) more pus was evacuated. This pus had been retained in three lateral pockets formed by collapse of the walls of the abscess about the rubber drainage tube so firmly that pus could not escape. A cross section

of the abscess would have been the shape of a three-leaf clover. After 45 c.c. of cerebrospinal fluid was removed, the abscess was wide open and measured about 2½ inches in depth and 2 inches in diameter. It had a smooth pinkish red lining about 4 mm. thick. An iodoform gauze "handkerchief" with inner iodoform strips was placed in position in the usual manner and a copious head dressing applied. Condition after operation was good.

On the second day postoperative the superficial dressing was changed. A spinal tap was done, 45 c.c. fluid removed and, after removal of the inner iodoform strips, a well-like cavity was seen. The handkerchief was not disturbed. The general condition was good. The herniation was controlled by frequent lumbar punctures. On the eighth postoperative day temperature was 100, and the pulse averaged 85. There was at this time only a dimple-like cavity about ¾ inch long, ⅝ inch wide and ½ inch deep. The wound had not been dakinized and there was some purulent reaction which is not seen in a well dakinized wound. Azochloramid was used because Dakin's solution was not available at that time.

On the tenth postoperative day all of the original gauze was removed, replaced in the usual manner, and dakinization was begun. On the fifteenth day, the temperature was 99, the pulse 82. The wound was granulating, and slight herniation was controlled by spinal taps, catharsis, enemata, elevation of the head and restriction of fluids. The patient was up and about the ward on the thirtieth day. He made an uneventful recovery.

The patient left the Jersey City Medical Center the day before Thanksgiving in 1937 and went to his home. He returned to his usual work in a gasoline station in February, 1938 and has worked there steadily ever since. He gets along without any trouble, has no complaints and does his regular work in the usual manner.

RESULTS

Of sixty cases of brain abscess of all types observed in the period from 1920 to 1939, seven cases were of traumatic origin. Three resulted from punctured wounds of the brain; one was produced by a thrown pair of scissors, one by a knife-blade producing a self-inflicted wound through a preëxisting cranial defect, and one by a broken-off knife blade which remained in the brain over twenty-eight years. Two resulted from fractures involving the mastoid in one instance and the frontal sinus in the other. One developed late after a self-inflicted gunshot wound of the skull and brain, a 45 caliber service pistol bullet inflicting the injury. One formed after the operative site of the compound fracture of the skull was well healed. All were males, ranging in age from 7 to 54. Four had convulsions before operation, and one, the patient with the gunshot wound, had

convulsions after operation. Seven were operated upon and all made uneventful recoveries.

DISCUSSION

W. GAYLE CRUTCHFIELD (Richmond): In the discussion of this subject, I believe that prevention should be stressed. There would be few brain abscesses of traumatic origin if patients with lacerations of the scalp and compound fractures of the skull received early treatment consisting of thorough debridement.

Dr. King's method of treatment and his meticulous postoperative care of patients speak for themselves. Such a high percentage of cures is an unusual achievement. We have used Dr. King's operation with a high degree of success but usually we have reserved it for those abscesses that fail to heal after continuous catheter drainage or repeated tapping.

Dr. King has not mentioned sulfanilamide as an adjunct to surgery. I am of the opinion that with the aid of this drug we may be able to obtain more cures with his as well as other methods of treatment.

JOHN RAAF (Portland, Oregon): I might paraphrase a statement by Osler and say, "From Macewen, who made one of the earliest contributions on the subject, down to the present time, the treatment of brain abscess has been one long traffic in hypophysis." Almost every surgeon who has treated a number of patients with brain abscess has devised his own method of treatment of the condition. Some surgeons advocate the multiple tapping method; some prefer to insert a small rubber catheter into the abscess cavity and allow the abscess to drain through the catheter; while others open the abscess cavity widely, view the interior of the cavity, insert hard rubber tubes, and pack about the tubes with gauze. Dr. King prefers still another method. I believe that those surgeons who are so attached to their own method of treatment of brain abscess and in effect say, "Come follow me and leave the rest of the world to its babblings," are assuming the wrong attitude, for I do not believe that every brain abscess can be treated by the same method. The selection of the method of treatment depends on the portion of the brain in which the abscess is located and the depth of the abscess from the surface as well as the length of time the abscess has been present.

Certainly there is something to be said for Dr. King's method of treatment. Nine days ago I was present at an autopsy upon the body of one of my patients whom I had operated on for brain abscess. The abscess had followed a frontal sinusitis and an osteomyelitis of the frontal bone. The abscess cavity was huge; I had opened it widely, sucked out the contents, inserted hard rubber tubes, and packed about the tubes with gauze. All had gone well for ten days, and then cerebrospinal fluid suddenly began to drain from the hard rubber tubes, and the patient subsequently died of meningitis.

One must remember that after an abscess cavity is evacuated, the wall of the abscess will advance upward; and if the tubes are not withdrawn

rapidly enough, they will push their way through into the ventricle as happened in this case. Dr. King's method of packing the abscess cavity with gauze would have been, I believe, preferable here.

I should also like to add my "amen" to Dr. Crutchfield's plea for adequate treatment of head wounds at the time of injury. Repeatedly one sees patients who have compound comminuted fractures of the skull which are inadequately treated. The attitude frequently taken is that the patient will die anyway so why bother with careful suturing of the scalp wound. As soon as the patient has recovered from the initial shock, he should be taken to surgery, and a thorough debridement of the wound performed. If this is always done, the wound will in a majority of instances heal by primary intention. This not only will eliminate the danger of subsequent formation of a brain abscess, but if at a later date some condition such as subdural hematoma is found to be present, the surgeon has a clean operative field in which to work.

Joseph E. J. King (closing): I want to thank Dr. Crutchfield and Dr. Raaf for their very kind remarks.

I have not used sulfanilamide in cases of brain abscess since I have had no cases complicated by meningitis since the drug was brought out. Should I have to treat a case with an associated meningitis, I would surely use sulfanilamide. I have never resorted to simple tapping alone.

We have had what might be considered rather good results, but I do not insist on the sole use of the method which I have described. In my hands it has proved efficacious in most cases. We have had thirty-five patients who had, by any stretch of the imagination, some chance to recover. Some of the sixty patients were dead or moribund when I first saw them, and in a number, suppurative leptomeningitis had already developed, while in several more the lesions were multiple metastatic ones.

Thirty-one of thirty-five patients recovered, and four died. Three deaths are believed to have been preventable. One was due to a nurse's pouring eggnog down the trachea of a patient who was comatose, and she literally drowned. In another case the dressing was done by someone else in a distant hospital, and the bandage was removed by the patient who clawed into the brain substance and reinfected the brain. Another, a child, developed pneumonia due to having been placed by an open window in the winter, while dakinization was being carried out.

Dr. Crutchfield was very unassuming in his remarks. He and Dr. Coleman have had splendid results in a number of abscesses.

I could go into the different types of procedures, but time will not permit. The tube drain, of which Dr. Raaf spoke, has several disadvantages. It may become dislodged and slip out of the drainage tract, and when an attempt is made to replace it, it may be pushed into the brain substance itself and not into the tract. A secondary pocket may develop due to insufficient drainage of the abscess, and it may rupture into the ventricle in the same manner as an original abscess. Or, the tube may be held firmly in

place, and the distal end be thrust in bayonet fashion through the floor of the abscess into the ventricle. I feel sure that most surgeons dealing with brain abscess have had these experiences.

We have been fortunate in that we have not had a fatal meningitis with the exception of one case with gross rupture into the ventricle in an unmanageable patient. We have performed but a single operation for any given abscess, and have not had to resort to multiple operations or explorations.

In six cases in which colleagues had used a tube to drain the abscess, I have oserved that a small tube would be placed into the abscess cavity, a considerable amount of pus would drain out, and the patient would improve for about four or five days. Then the surgeon would notice that the patient was not "doing so well." When I was called to see the patient and removed the dressing, the end of the tube could be seen sticking up above the wound, in some cases with slight herniation of the brain, and not a bit of pus exuding from the tube. Nevertheless, the patient would be quite ill.

When the patient was placed on his side with the tube directed upward, and lumbar puncture was done, pus would begin to ooze out through the wound, both through the tube and alongside it, as the fluid was removed through the lumbar puncture needle. In most instances the amount of the cerebrospinal fluid removed would range between 35 and 45 c.c. By the time this amount was removed an enormous outflow of pus would take place. On exploration of the tract and dilatation of the external opening, one could observe that the abscess cavity was partially collapsed about the tube, leaving a pocket at thirds in the circumference of the abscess, so that a cross section of the abscess cavity and pockets with the tube in place would somewhat resemble a three-leaf clover. With removal of the cerebrospinal fluid, the cavity again became dilated so that only one cavity was present, and the pockets would disappear. When the cavity had opened widely, it was treated in the manner described, and in all six instances the abscesses healed.

THE USE OF ANTISEPTICS IN THE TREATMENT OF OPEN WOUNDS

W. L. Estes, Jr., M.D.

BETHLEHEM, PENNSYLVANIA

ANTISEPTICS may play a dual rôle in the treatment of an open wound: (1) their application to the skin about the wound to prevent further contamination of the wound by skin bacteria; and (2) their use as germicides in the wound itself.

Strong and convincing argument in recent years, notably by Reid and also by Koch and Mason has been advanced to indicate the harm that the indiscriminate use of irritating antiseptics in fresh wounds may cause in the prevention of rapid and complete healing. If soap and water and copious amounts of saline are used to irrigate carefully and thoroughly every portion of the wound, infection can be prevented and antiseptics in the wound itself are rendered unnecessary. Reid regards the fundamental concepts upon which proper treatment of the wound should be based as:

1. Hemorrhage is to be controlled.
2. Bacteria for the first six to eight hours are on the surface of the wound and are not invading and therefore simple mechanical irrigation will suffice to evacuate them.
3. Bacteria destroy nutritional support to and kill living cells.
4. Debris, clots, foreign bodies, and devitalized tissue promote bacterial growth.
5. Fresh wounds are rarely completely free or freed from bacteria. Their sterilization is relative.
6. Healthy living cells have great power to combat bacteria.
7. Healing occurs by growth of living undamaged cells.
8. Stimulus for growth of living cells is probably from the cell damage or chemical change in the wound.
9. Rest of the part injured promotes healing.

The important essentials in treatment are, therefore:

1. Control of hemorrhage.
2. Careful and thorough removal of debris, foreign bodies, clots, and devitalized and non-viable tissue (debridement).
3. Mechanical cleansing by irrigation, very thorough and gentle, to avoid damage to the remaining healthy living cells.
4. Few fine ligatures.
5. Splint to rest the involved part.

Treatment of an open wound should be inaugurated as soon as possible after the injury, certainly within six hours of the accident if infection is to be prevented. It should comprise:

1. Control of bleeding and protection of the wound. This can usually be accomplished in small wounds by covering the wound with sterile gauze and making pressure upon it. Large wounds may require for control of hemorrhage a tourniquet well above the traumatized area or a hemostat on the bleeding vessel.
2. Cleansing and sterilizing of the skin around the wound. This is best accomplished by:
   (*a*) Soap and water.
   (*b*) Alcohol.
   (*c*) Alcoholic antiseptic—tincture of merthiolate, or of bichloride of mercury.

Soap and water not only mechanically cleanse the skin, but have definite antiseptic power. When skin is relatively mechanically clean, alcohol and an alcoholic antiseptic may suffice. If soap and water are used, plenty of alcohol to dehydrate the skin should follow. If alcohol is not used, penetration of the antiseptic to the deeper glands of the skin is very slight and wound contamination from the skin is more likely. Experimental proof is not lacking to indicate that alcoholic solutions of antiseptics are more efficacious in destroying bacteria of the skin than watery solutions. Care should be taken that the skin antiseptic should not enter the wound.

3. Protection of the skin around the wound with sterile towels or covers.
4. Cleansing of the wound.

The wound should be very gently washed out with soap and water and irrigated with saline. All clots and foreign material—grit and gravel, and free debris—should be removed. Large bits may have to be lifted out with forceps. Cleansing should be done most painstakingly and methodically, beginning with the skin margins, then continuing with the subcutaneous fat and finally the muscle and fascia. All interstices of the wound should be reached. The opening in the skin should be enlarged whenever necessary to permit complete visualization of the wound. Finally, debridement of all devitalized tissue and dirt containing tissue must be thoroughly and carefully done, i.e., beginning with the skin margins, the subcutaneous fat, and finally proceeding to fascia and muscle. After debridement, the tourniquet, if used, is removed and all bleeding points ligated, and again the wound is thoroughly, gently, and

methodically cleansed with saline. (In laceration of the scalp with open fractures of the skull, diffuse saline irrigation is contraindicated; saline should be used freely, but only in small amounts because of the possibility of extensive flooding carrying infection to the meninges.) Only the finest ligature material should be used, whether silk or catgut, and as little tissue as possible should be included in the tie in order to avoid the pressure necrosis of ligature en masse that will cause breaking down of the wound. The manner in which all this is accomplished, how gently and thoroughly the procedure is executed, and not simply the procedure used, determines the success of treatment.

5. Drainage, closure, and splint.

In large wounds, drainage, particularly dependent drainage, is frequently indicated. Finally, the wound is sutured or packed wide open with vaseline gauze, or the Carrel-Dakin treatment is instituted, according to the specific indications in each case, and a snug but not tight bandage, splint, or cast applied to insure rest of the part.

COMMENT

Meticulous, careful and prolonged use of soap and water and saline will usually suffice to rid the wound of bacteria. These solutions are not destructive to the tissues, and make the use of antiseptics, as a rule, superfluous.

However, those who have had wide experience in the treatment of trauma have recognized the greater potentiality for and danger of anaerobic infection, notably with the gas or tetanus bacillus, presented by soil (particularly highly cultivated soil), contamination of wounds, in contrast to the usual industrial wound. Even in the face of the universal condemnation of antiseptics in the treatment of open wounds it seems to me that we should nevertheless weigh carefully the necessity and advisability of the use of antiseptics for this type of contamination. A case of tetanus (referred to our clinic), which developed four months after the original injury, antitoxin having been given, and the occasional case that has been reported in which tetanus has occurred in spite of adequate treatment of the wound and the prophylactic use of tetanus antitoxin suggest that in these soil contaminated wounds something more than the routine use of soap and saline, no matter how exhaustively and meticulously employed, is advisable. Most commonly these wounds are considered potentially liable to anaerobic infection and should not be sutured, but are best treated by the Carrel-Dakin method or by

packing wide open with vaseline gauze. It has seemed reasonable, therefore, if Dakin's solution is to be used in these wounds following the soap and saline routine that it would be logical to use Dakin's solution instead of, or following, saline in the actual irrigation of the wound as part of the primary treatment. Furthermore, Dakin's solution is a strong oxidizing agent as well as a powerful antiseptic and is easily obtained with proper pH and potency by simple dilution of the commercial concentrated solutions such as hychlorite or zonite. Certainly, if there is available a non-irritating and nontoxic antiseptic that would not damage tissue or alter in any way normal tissue repair it would be well to consider its use in these peculiarly contaminated wounds.

We have, therefore, in a small series of 150 cases, used Dakin's solution where gravel or soil contamination had occurred, especially to ascertain (1) the incidence of infection after this treatment; (2) if delay in healing or breaking down of the wound resulted.

All these patients had injuries of sufficient magnitude to warrant admission to the hospital and remained under observation while healing took place. In only three did any infection occur, and these were all lacerations of the cheek into the mouth, a type of wound in which recontamination from the mouth is seldom avoided. In three some serum, and in two a drop of pus was noted about the sutures at the time of their removal. In five there was sloughing of a widely undermined skin flap, but without infection. There was no evidence in any that the use of Dakin's solution was responsible for delay in healing, but one wound with extensive tendon repair seemed to show more deep scarring of the tissues than might be expected if saline only had been used. Reid has noted in experimental animals, in comparing wounds treated with soap and saline with wounds in which strong antiseptics had been used, that in those healing apparently equally well, there was often a thicker and less pliant scar in the antiseptically treated wound. Carrell has shown that in an open wound in which one-half was treated with saline and the other half with Dakin's only a very slight retardation occurred on the Dakin side.

Twenty-five open fractures have likewise been treated with Dakin's solution for primary irrigation. Five of these were treated by packing wide open with vaseline gauze; ten by complete closure of the wound—all these were joint fractures; in nine the wounds were sutured and drained; and in one the Carrel-Dakin method was employed. In one of the cases where packing with vaseline was done there developed a slight superficial infection with

Staphylococcus albus, which did not influence the healing of the fracture.

From this very small series obviously no positive conclusion is justified, but these preliminary observations would seem to indicate that Dakin's solution does not interfere materially with healing and should serve as *an added safeguard* in the soil contaminated wound.

However, it is to be emphasized that the use of Dakin's solution or any antiseptic in the soil contaminated wound must be regarded merely as *an added safeguard*. The main essential in preventing anaerobic infection in these wounds is a thorough and meticulous debridement; i.e., removal of *all* the devitalized tissue, particularly devitalized muscle, the ideal pabulum for bacterial growth. Likewise, the prophylactic employment of tetanus and gas bacillus antitoxin is highly important—5,000 units of tetanus antitoxin instead of the usual 1500 will be more efficacious and this may be repeated in ten days in suspicious cases, as Garlock has suggested. As sulfanilamide has been shown to be effective against the gas bacillus, its routine use to prevent the possible onset of infection should have merit (Ogilvie).

DISCUSSION

There have been but a few investigations that bear upon the toxicity of antiseptics for tissue. Dakin found that bichloride of mercury, nitrate of silver, and iodine were all irritating to the tissues, but that Dakin's solution destroys *necrotic* tissue and does not damage tissue with a circulation. Smelo (1936) has reported merthiolate less toxic than phenol, iodine, mercurochrome and metaphen but not an ideal antiseptic because it is more toxic to connective tissue and epithelial cells than to bacteria. McClure has been interested to obtain an antiseptic, not destructive to tissue that could be used with tannic acid in the treatment of burns. He has reported the mercurials, bichloride, metaphen, merthiolate, as having a high toxic coefficient, with the cresols and hexylresorcinol relatively low. Meleney, for the anaerobically contaminated wound, has suggested the use of zinc peroxide where contamination with anaerobic and microaerophilic organisms was suspected or inevitable. The zinc peroxide, to be effective, must be applied as a creamy suspension in sterile distilled water to every part of the wound surface. When delayed closure seems advisable, the wound may be packed wide open with gauze saturated in zinc peroxide.

It would seem that this should be a fruitful field for further experimental investigation.

SUMMARY

Efforts to treat an open wound to promote rapid healing without infection must be directed first to the control of hemorrhage and then to the removal of all debris and devitalized tissue by irrigation with saline, but so gently, carefully, and thoroughly, as to wash out and rid the wound of every free necrotic bit, but not to damage the healthy tissue remaining. This is by far the most important element in the treatment. The most essential adjunct is debridement or excision of all the devitalized and contaminated tissue that is not free and cannot be washed out.

Antiseptics are of value in skin disinfection, but in the treatment of the wound itself are seldom necessary, and their indiscriminate use may harm normal processes of repair. An antiseptic, however, would be an added safeguard in anaerobically or soil contaminated wounds. In this category, it is suggested that Dakin's solution may be used. An ideal antiseptic for use in open wounds should possess effective bactericidal action and be nontoxic to tissues and not interfere with or delay healing.

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PRIMARY CLOSURE OF TRAUMATIC WOUNDS WITH ESPECIAL REFERENCE TO THE CONVERSION OF COMPOUND INTO SIMPLE FRACTURES

JOHN E. CANNADAY, M.D.

CHARLESTON, WEST VIRGINIA

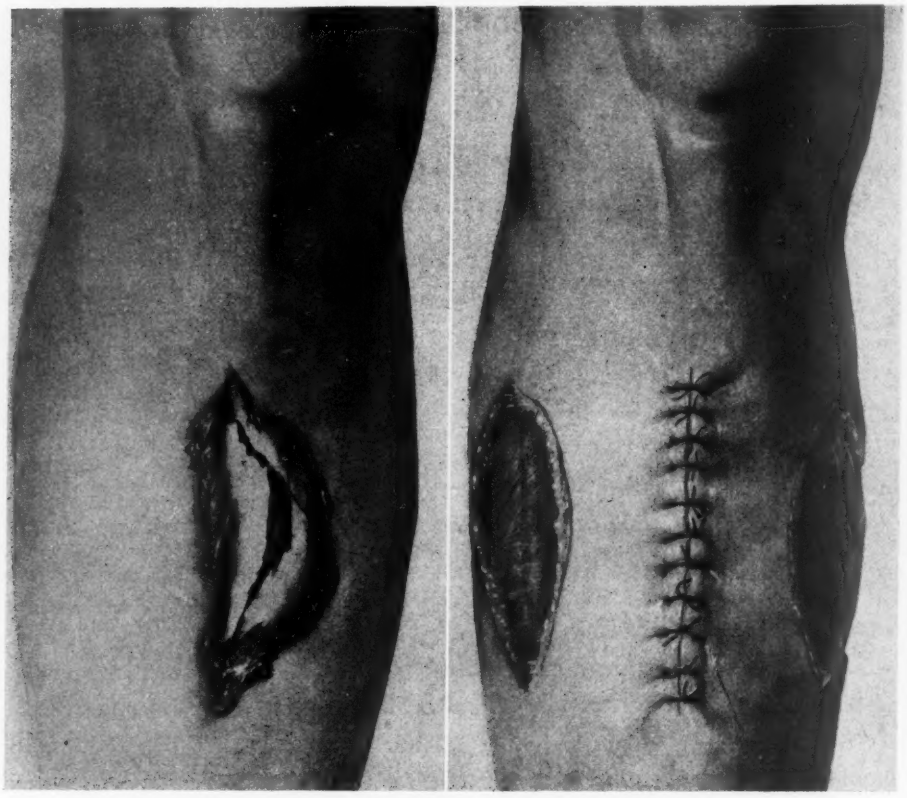
I APPRECIATE the fact that in advocating the early closure of compound fracture wounds, I am opening up a controversial subject. The surgical profession is to some extent divided into two camps on the subject, one advocating the Orr or other forms of open treatment, the other side leaning to early closure of the wound with the idea of converting compound into simple fractures and avoiding in many cases, at least, prolonged drainage, chronic osteomyelitis, sinus formation, disabling scars and other complications.

In 1924, Wilkinson[1] reported a series of fifty-four compound fractures in which primary closure had been done. Only 6 per cent became seriously infected. In 1929, I[2] reported the results in more than 100 cases of compound fractures treated by early skin closure in which satisfactory union was obtained in approximately 90 per cent. In this same communication I called attention to the value of liberating lateral incisions in dealing with certain of these cases in which excessive loss of skin or an unusual amount of swelling made it necessary to mobilize the adjacent skin to some extent in order to bring about closure of the wound without undue tension.

The neurosurgeons of this country have quite generally evolved a technique for dealing with compound fractures of the skull by the aid of local anesthesia, adequate antisepsis and asepsis with debridement, followed by closure of the wounds without drainage. Some of them are also recommending the use of relaxation incisions well outside the involved area so that a satisfactory closure can be brought about in cases in which there has been considerable loss of skin. Coleman,[3] Wilson,[4] and many others stress the danger of using drainage in such cases, especially if there is a concurrent injury of the brain, their belief being that the drain itself can and often does introduce infection, that it may create a sinus and be the cause of brain infection, edema and death.

The scalp, of course, has a rich blood supply and can thus overcome infection more readily than other parts of the body, yet it is

difficult for me to understand exactly why the difference of location should necessarily make such a vast difference in the preferred method of treatment. However, I will grant the premise that some



A B

FIG. 1. A, compound fracture of tibia with extensive exposure of bone at point of fracture. B, showing liberating lateral skin incisions, allowing suture of skin wound over point of fracture. (From Cannaday, in *Ann. Surg.*, April, 1929.)

wounds may be so badly lacerated or so grossly contaminated that it would be foolish to attempt a primary closure; otherwise patients in a bad state of shock are not in condition for any prolonged operative procedure. It is also quite possible to secure good results by more than one method of treatment.

It is obvious that in conjunction with this method adequate immobilization is absolutely necessary. It will be argued that in some cases at least there will likely be an accumulation of serum in the wound, particularly when a certain amount of dead space is present. Most of the men quoted state that in such cases they practice loose closure in order that drainage by seepage or leakage may take place. This particular method of wound closure was practiced by Sir Arbuthnot Lane[5] in his no-hand-touch-technique for the internal

fixation of fractures of the long bones by the use of metal plates. The majority of the surgeons whose methods have been studied do not make a general practice of using drains.

It is taken for granted that the method described will be carried out in well equipped hospitals and by surgeons adequately skilled in the surgical technique and asepsis that should go along with any major operative procedure.

TECHNIQUE

The application of a first aid sterile compress of gauze which may or may not be saturated with an antiseptic solution is routine, while thorough emergency splinting of the part is, of course, necessary for satisfactory transportation of the patient. The methods in general use for the cleaning up of a compound fracture include the free use of liquid green soap and warm water. Shaving about the wound is followed by prolonged and thorough irrigation of the laceration with large amounts of normal saline solution. The skin about the laceration is painted with some antiseptic, the area is draped and an extremely thorough but conservative debridement is done, including grossly contaminated bone which can be pared away by the use of the chisel or rongeur. If possible the fracture is reduced, after which the skin wound is closed if it is practicable to do so, with due regard for the length of time which has elapsed since injury, the nature and amount of contamination, and the available skin present.

It is necessary that the debridement be carried out in meticulous detail, enlarging the skin opening if necessary for the proper inspection of all parts of the wound and for the purpose of extending the debridement into the ultimate recesses of the wound, and thoroughly cleansing and debriding contaminated bone ends as well. In case there is much dead space or likelihood of an accumulation of serum, the suturing is lightly done in interrupted fashion so that any accumulation of fluid can drain out by seepage between the sutures. In some of these cases, owing to excessive loss of skin or swelling, it may be necessary to make free liberating incisions laterally in order to be able to bring the skin edges together; likewise to allow adequate drainage from the wound by seepage underneath these skin flaps. Drains are dispensed with whenever it seems safe since they undoubtedly may introduce infection from the outside and predispose to sinus formation. During the process of debridement it is deemed advisable to redrape the area, likewise to change gloves and instruments, especially in dealing with the more extensive and

complicated wounds.* At this time the reduction of the fracture and the fixation of the limb must be brought about in a positive manner by plaster casts, splints, wires, pins, or other forms of traction and countertraction.

Quite a few surgeons practice keeping the wound covered with alcohol soaked or dry sterile gauze during the time in which the scrubbing and shaving of the skin surrounding the wound is taking place. The extremely thorough cleansing of the wound itself both before and after debridement with large quantities of saline is the method most favored at this time.

At the time of debridement, the skin edges and all badly damaged skin are removed, along with all lacerated or damaged tissue aside from major blood vessels and nerve trunks and tendons. Small detached bony fragments are removed, but larger fragments and especially those attached by periosteal strips are not removed. Soiled bone ends are debrided by use of a rongeur or chisel, with care not to sacrifice too much bone. Even simple punctures are explored carefully as they may contain foreign material. Bleeding points are ligated with fine catgut. After a painstaking debridement has been carried out, the wound is again irrigated with copious amounts of warm saline solution. Internal fixation of the fracture by metal plates, screws or wires is not generally felt to be advisable as it may lead to prolonged infection. Control of the fractured bones by skeletal traction is favored as being a comparatively safe and positive method.

Wounds which have been carefully debrided within six to eight hours after injury, may often be closed without drainage. Those treated eight and ten hours in many cases may likewise be sutured somewhat loosely to allow for possible wound drainage. Buried sutures are not used except for hemostasis and repair of tendons and nerves.

If a plaster cast is applied an adequate window should be cut over the wound for purposes of inspection.

A few illustrative cases are appended.

* Since March, 1939, we have been implanting sulfanilamide crystals in traumatic and other potentially infected wounds. We have observed a lower incidence of infection as a result of the use of this method. More recently we have also been using a 3 per cent solution of cocoanut oil soap in the cleansing of wounds, this being followed by free irrigation with normal saline solution. It is felt that this soap solution is distinctly bactericidal and not only helps to eliminate contamination of the wound received previous to operation but likewise to eliminate most of the wound contamination from the air-borne bacteria which are undoubtedly present in large numbers in all operating rooms.

CASE REPORTS

CASE I. A woman, 68 years of age, in crossing a dusty road in midsummer was knocked down by a car. She received a compound fracture of the tibia and a simple fracture of the fibula. The tibia had broken through the skin and protruded for at least 2 inches. As her condition was good, she was at once given ether anesthesia, the wound was flooded with freshly prepared tincture of iodine followed by alcohol and then carefully debrided. The projecting end of the tibia which had apparently been grossly contaminated was pared away with a rongeur. The fracture was reduced and the wound was closed with silkworm gut sutures. These were allowed to remain in place for approximately two weeks. The leg was supported by a plaster cast with a window for dressings. Primary skin union took place. Bony union was delayed but took place in the course of four months.

CASE II. A mine foreman who had been badly injured in a slate fall was sent to me for treatment. He was not at all well at the time of injury and had had a persistent cough for some time past.

On examination he was found to have a simple fracture of the left forearm and left femur, a simple fracture of the fibula of the right leg and a compound fracture of the tibia of the same leg, with considerable loss of soft tissue over the anterior surface of the tibia at the point of fracture. He was in a state of shock and was treated for this. A dressing of gauze and cotton wet with merthiolate solution was applied over the wound. By the next day his condition had improved somewhat and at this time under local anesthesia, debridement of the compound fracture area was done. Rather long liberating incisions had to be made on either side of the leg in order that a satisfactory closure over the bone might be brought about. The fracture was reduced and the soft tissue wound closed with interrupted silkworm gut. The leg was held in position by a long posterior splint with a footpiece attached. After closure it was observed that each of the lateral incisions was approximately 4 inches long and that there was a bare gap about 1½ inches wide about the center of each lateral incision.

The operation proved to be successful. One month later the original skin wound over the fracture was perfectly healed. The granulating surfaces left by the liberating incisions had narrowed down to approximately ¼ inch in width at the widest point. For a time there was fibrous union of the fracture. In the course of three and one-half months firm union was present.

CASE III. In a compound fracture of the tibia and simple fracture of the fibula of eight hours' duration, the wound was cleansed, debrided and sutured under general anesthesia. However, it was closed with more tension than was desirable. Stay sutures of silkworm gut were used. A plaster cast with window was applied. Ten days later the wound broke down, but the walling off of the fracture had progressed so far that the bone was covered with healthy granulation tissue and no evidence of deep infection developed. Later the gap in the skin was covered by skin grafts. Firm bony

union took place without untoward event. It was obvious that the protection afforded by the skin, even temporarily, gave time for the building of a defensive wall at the site of fracture.

CASE IV. A male, aged 25 years, was admitted to the hospital with a recent compound fracture of the right femur resulting from an injury when his right leg was caught between a mine car and a post. His doctor applied a long wooden splint to fix the fractured limb, dressed the wound and sent the patient to the hospital.

The patient was not in shock, the lower portion of the right femur projected more than an inch through the skin and was badly soiled with coal dust. *X*-ray revealed a comminuted fracture just distal to the trochanter with marked upward and outward dislocation of the shaft of the femur.

Immediate operation was done. In addition to the usual soft tissue debridement a careful paring of the contaminated end of the bone was carried out with the aid of a rongeur. A Steinmann pin was put through the lower end of the femur. The fracture was reduced and the wound was closed with interrupted sutures.

X-ray checks were made on the leg from time to time and while they showed a very slight upward displacement of the shaft, the femur outline was good and the position of the fragments such that a satisfactory result seemed likely.

The patient's temperature during convalescence went a little above 100°F. three or four times, but other than that it remained normal. When he was discharged from the hospital he walked with the aid of crutches which were later replaced with a cane. He was able to return to work five months after discharge.

CASE V. A child, 6 years of age, was admitted to the hospital with a compound depressed fracture of the skull over the frontal parietal area. About one-half hour after the accident, the wound was debrided and sutured. It was found that the dura had suffered a moderate laceration, but the surgeon did not consider it necessary to apply a fascial graft. A small amount of traumatized brain tissue was removed. The wound was debrided and closed with black silk sutures. It was inspected from time to time and remained apparently clean. Seven days later, when the patient's head was being dressed, it was noticed that there was a serous discharge from the wound, that the skin edges had separated and that brain tissue was definitely bulging through the wound to a level of at least ¾ inch above the pericranium, also that the pulsations of the blood vessels were pushing this hernia up and down in a most alarming manner.

I saw this case in consultation and advised that another debridement and a secondary closure be made. The child was again anesthetized, the brain hernia was scooped out with the electrosurgical unit and the skin edges freshened. Since the retracted skin edges would not meet, free liberating lateral incisions were made, after which the wound was closed with sutures of black silk and the lateral incisions were packed with iodoform

gause. Healing took place without untoward incident and the result has thus far been satisfactory. No apparent bulging has occurred.*

The subject of compound fractures is of such great importance it is worthwhile to present the collective views and methods of a number of surgeons who treat considerable numbers of such cases. Letters of inquiry have been sent out to a number of these men, to determine whether or not they favor debridement and primary closure of wounds, especially in those associated with compound fractures. We find that the majority of them do favor this method of treatment. A very few, Sherman[6] and Campbell,[7] apparently favor leaving practically all compound fracture wounds open. The replies have been abstracted below.

Sherman favors dakinization followed by secondary closure when practicable.

Graham[8] says that he has definite figures on eighty cases treated by primary closure, at the Memorial Hospital in Richmond, thirty in one series and fifty in another. He believes that there have not been more than four serious infections in the entire group.

Cotton[9] states that loose closure with interrupted sutures which allow drainage by leakage rather than the installation of a drain frequently offers the best solution of the problem, but that a rigid technique is very necessary to the success of the method.

Pfeiffer and Smyth[10] say that immediate closure should not be attempted unless the surgeon is capable of carrying out an extremely careful technique. Naturally the degree of contamination and the amount of damage that has been done to the soft tissues would have a great bearing on the outcome.

Baldwin[11] favors primary closure, practices posterior or gravity drainage and uses tincture of iodine to disinfect the wound. Sometimes he irrigates with a dilute iodine solution followed by saline.

Swart[12] has been making use of primary closure in compound fractures for sometime past and finds that the results from the standpoint of primary healing are reasonably satisfactory and that in a good many instances, a slight wound infection may not seriously interfere with early and satisfactory union. He is of the opinion that the method is well worthwhile.

Anderson[13] uses closure in most of the cases that come from the mines if he sees them early. Cases that are badly contaminated he leaves open. He uses normal saline to cleanse the wounds.

* This case is from the neurosurgical service of Dr. Archer A. Wilson who made the final closure.

Scott[14] has been continuing the technique of careful debridement and primary closure for several years and has found it very satisfactory. His percentage of infection is low (he would estimate it to be less than 10 per cent). He does an extensive debridement and washes out the wound with large amounts of normal saline.

Estes[15] believes, as no doubt we all do, in treating each case on its own particular merits. He feels if the outcome of the case is doubtful it is better to leave the wound open. His decision to close or not depends greatly on the extent of muscle damage that is found, irrespective of the wound through the skin. When there is extensive muscle damage he does not close the wound primarily. A wound that has been contaminated with soil he does not close unless he feels that the debridement has been very satisfactory; usually he treats the wound in such cases by the Carrel-Dakin method. In general, he says that he seldom closes a compound fracture of the humerus or femur but is more apt to close a fracture of the tibia in which there has been little muscle damage, or fractures of the forearm in which there has been little or no injury to the muscle. He favors extensive irrigation and exploration of the wound, incising the skin if necessary, and following this in many cases by the use of Dakin's solution. Thorough debridement of the entire area is followed by a search of all the interstices of the wound and further irrigation with Carrel-Dakin solution, especially for the large wounds. Small wounds he may pack with vaseline gauze. Superficially situated wounds associated with compound fractures he may close with loosely tied interrupted sutures.

Rankin[16] tries to carry out a thorough debridement and follows this by closure, especially in cases that have been received within six hours of the accident. He expresses his opinion that 90 to 95 per cent of these cases heal by primary union. He, of course, excepts cases that have had soil contamination. After six hours he thinks considerable judgment has to be used and if the injury has gone for more than twelve hours, he thinks it should usually be treated by the open method. He has no hesitancy about using internal fixation, if necessary, for early fractures. In cases that are seen two or three days after the accident occurs, he considers it very dangerous to attempt manipulation.

Funsten[17] has treated more than 300 cases of compound fracture in the past six years and has closed most of them after extremely thorough debridement. He fells that the percentage of seriously complicating infections will not reach more than 8 per cent, perhaps less. In cases that are seen late and in some where the usual complete

debridement is handicapped he continues to use drains, but removes them in forty-eight hours through windows in the casts if the temperature is normal. His percentage of gas bacillus infection has been very small, perhaps partly due to the efficiency of the gas bacillus antitoxin.

Stallard[18] continues to close early compound fractures after debridement, using interrupted sutures loosely placed with a window cut in the cast for dressings if necessary. He also places his patients on prophylactic prontylin therapy to counteract the possibility of infection.

Byars[19] practices early closure of the soft tissues associated with fractures of the face and uses drainage if the condition of the wound seems to indicate it. Wounds of the floor of the mouth are never tightly closed. He says that some of them are packed with gauze; in other cases an opening for drainage is made underneath the chin. Lacerations under the mandible associated with fractures are closed early but drains are inserted to the fracture line. In other words, in a wound so situated as to be contaminated by mouth secretion, he uses dependent drainage if possible.

Bailey[20] considers every compound fracture case an individual proposition and does not desire to close such a wound if it has been exposed to an environment that might encourage severe infection. He often closes the wound that permits careful scrutiny and where antisepsis may be applied. He fears the tendency to pull too far toward the radical closure of preinfected wounds.

Outland[21] uses the Böhler technique in the treatment of compound fractures. This essentially consisting of immediate complete debridement followed by closure of the skin alone, no deep sutures being used except in case of nerve or tendon lacerations. A tube drain is inserted to the depth of the cavity about the fracture and passed through a small stab wound away from the original wound. He believes that this insures drainage in case of infection and also relieves tension on the suture line. The drain is removed in forty-eight hours if no sign of infection is present. He states that his real difficulty is with the small puncture wound associated with fracture. The question of whether to debride or not to debride he usually settles by merely applying a sterile dressing. In such cases he feels that if surgical operation is undertaken, the incision should be enlarged and a complete excision of the damaged tissue done.

Garr[22] as a rule closes primarily compound fractures in which there is no excessive damage to the skin and soft parts. He thoroughly debrides the wound, carefully cleansing about it with ether,

alcohol and tincture of merthiolate, puts in interrupted sutures rather far apart to allow free outlet for any seepage that may develop. He does the same thing in larger wounds but usually puts in a small wick of vaseline gauze down to the site of fracture which is removed in a few days if infection does not develop.

Prillaman[23] debrides and closes most compound fractures, installs Carrel-Dakin tubes (usually one or two) beneath the suture line and irrigates the larger wounds with Dakin's solution. When the temperature indications are favorable the tubes are removed.

Vance[24] believes that soft tissue wounds associated with compound fractures that are not too severely traumatized can be debrided and closed. If there is a very great loss of soft tissue and it does not seem possible to do this well he leaves the wound open. If wounds are very small he usually does nothing to them at all.

Carothers[25] makes it a practice to close the wound wherever possible, providing, of course, the case is seen within a reasonable length of time. He considers eight hours about the longest time after which immediate closure can be carried out. He makes relaxing incisions in the skin on one or both sides, if necessary, in order to get a complete closure of the skin over the point of fracture. If relaxation incisions are made immediate Thiersch grafts are applied to the newly exposed raw surfaces. In case of badly lacerated wounds after debridement he closes loosely so as to allow drainage. His luck with primary closure of wounds in compound fractures has been so good that he believes in carrying out this procedure whenever it is anatomically possible, if the case is seen within eight hours. He cleanses the wound thoroughly with saline and even if there is no fracture he splints the limb to cut down the trauma of movement. In compound fractures, in addition to splinting, he usually uses two pin traction.

Strickler,[26] in handling compound fracture cases seen early, usually does a thorough cleansing followed by a careful debridement, sutures the tissues loosely and occasionally uses a small rubber tissue drain. He does occasionally pack the wound with vaseline gauze after cleansing and debridement. His results in both the procedures have been about the same, but of course wounds packed with vaseline gauze require a very much longer time for healing.

Brenizer[27] favors primary debridement followed by secondary closure about a week later if no infection is present.

Boland[28] says in regard to the primary early closure of soft tissue wounds associated with compound fractures his rule has been in small wounds to cleanse, but make no attempt at closure. In

large wounds a thorough cleansing is done and the wound closed after thorough debridement.

Sullivan[29] believes in individualization and careful discrimination. His tendency is toward primary closure after chemotherapy and careful removal of traumatized tissue. If excessive tension is found, especially in the skin suture line, he attempts to relieve that tension by lateral incisions with elevation of the flaps for the purpose of covering the fracture as well as providing drainage for the injured area.

Where contamination by foreign bodies such as grease, clothing, dust, etc., is evident, closure of the wound is delayed until no evidence of infection is present, then secondary closure is made. Proper attention to the fracture by skeletal traction and fixation by plaster or splints is carried out in detail. The nature of the treatment of compound fractures demands proper hospital facilities for a successful outcome. Under less favorable environment he believes in reducing the fracture and maintaining reduction as best can be done at the time and leaving the wound open.

Trout[30] believes in individualization, thorough cleansing, thorough debridement. His general policy is to close incisions without drainage.

Stack and Magnuson[31] cleanse the surrounding skin with soap and water after covering the wound with sterile gauze dressing. The skin around the wound is shaved and cleansed again, after which the wound itself is thoroughly cleansed. A careful debridement including the skin edges is done and this is followed by irrigation of the wound with normal saline. The wound is then closed and the fracture treated as a closed fracture. If during the course of the operation they feel that any instrumental manipulation of the fragments will enable them to bring about a proper realignment, this is done with minimal trauma. They do not use internal fixation during this phase of treatment. They believe that the closed method of treatment is usually successful if carried out within a period of eight hours. After this safe period the same procedure is done, but the wound is closed quite loosely and warm moist dressings are applied, secondary closure being contemplated when the absence of infection is assured. Older wounds in which frank infection is already present, are treated in the usual open manner, either by irrigation or by the Orr method, depending upon which is deemed more suitable.

Battle[32] favors primary closure after debridement followed by the immediate application of a plaster cast.

Caldwell[33] favors early and thorough cleansing and debridement, including the removal of soiled bone ends. He advises against pouring strong antiseptics into the wound. If the case is seen early and the wound can be closed even, by making parallel releasing incisions, this is done. He feels that in case of extensive crushing injuries of the thigh muscles associated with fractures, the Carrel-Dakin treatment is preferable. He favors the Orr method in the more serious and highly contaminated cases.

Henderson,[34] in speaking of the treatment of wounds, makes the following statement: "One of the most important factors in the treatment of this type of wound is the cleaning with green soap and water. Scrubbing with green soap and water is of more benefit than are the chemical solutions." As to which wounds are to be closed without drainage, this, in his opinion, depends somewhat on the amount of time that has elapsed between the accident and the arrival of the patient at the hospital. After a number of hours have elapsed between the accident and the dressing most wounds are infected and drainage should be instituted. For most wounds, particularly those around the joints, the part should be immobilized.

Goodman and Reeves[35] advocate closure of compound fractures, especially in cases seen from six to eight hours following injury. In this classification of cases they do a complete debridement and do not drain as a rule.

Reid[36] has stated his conclusions following a special study of the subject of the treatment of open wounds. He says that for all practical purposes, up to about eight and one-half hours after the receipt of the wound, infection can be considered to be on the surface. After that the penetration will gradually go in deeper. He considers a thorough debridement under most scrupulous aseptic precautions to be absolutely necessary in such cases. Again he stresses the importance of closure without undue tension, the avoidance of strangulation of large blocks of tissue by ligation and the use of fine suture material rather than coarse in ligating blood vessels.

Golden[37] advocates a modified Orr treatment for most compound fractures, and thinks that other factors other than the absolute length of time have to be considered.

Ralsten[38] cleanses the skin thoroughly with green soap and water, using a scrubbing brush when necessary, and rinsing with ether. The wound is cleansed thoroughly with gauze and saline solution. The wound and adjacent skin are then painted with an antiseptic, usually merthiolate or mercresin and the field draped. A debridement is

done, with an attempt to stay on the conservative side and at the same time remove all soiled and devitalized tissue. Accurate hemostasis is secured at this time. The wound is closed without drainage and fairly snug dressings are applied. If a fragment is protruding, it is subjected to the same treatment as the soft structures. This author does not hesitate to apply an antiseptic to the wound or even to pool it there for four or five minutes before beginning closure of the wound. In some of his compound fractures he resorts to internal fixation, using vitallium plates. He states that in about 80 per cent of his compound fractures in which internal fixation has been done, he has had no infection and has secured good union. Although in some of these, signs of foreign body reaction developed after four to ten weeks and the plates and screws were removed, without such definite indication the plates were not removed. He believes in applying the above technique, especially in cases received in the hospital during the first eight to ten hours. In wounds received after this interval or in those patients whose condition upon admission is too critical for any kind of surgery, he allows the wound to remain packed open for a few days and then performs secondary closure if there are no signs of infection.

In some compound fractures in which the wounds were very extensive he performed the cleansing and debridement as mentioned, followed by reduction of the fracture. He then packed the wound open with vaseline gauze and applied a plaster cast in accordance with the Orr method. All these cases have eventually developed some infection and subsequent chronic osteomyelitis, but nothing of a severe type.

McMaster,[39] in discussing his technique, says: "The skin is washed with soap and water, grease is removed with benzine, and the hair is shaved, during which time the wound is covered with an alcohol-soaked or only sterile gauze." One of the standard antiseptics may then be applied to the skin, or as advised by Koch, the skin is again washed and cleansed with soap and water. He advocates primary closure in the case seen early, with the Orr treatment reserved for the cases that have gone for a longer period.

Kennedy[40] believes that sulfanilamide is of great value in the treatment of infected compound fractures. According to him, it was first used in this class of cases at Johns Hopkins Hospital in January, 1937, on a patient with a definite gas bacillus infection of a compound fracture. In the treatment of compound fractures fixed traction must be applied as soon as possible. Thought must be given to life and limb—and life comes first. In the limb we think of the fracture and

damage to the soft parts, and the soft parts come first. It is important that the patient be in the hospital not later than six hours after the accident, if possible, to avoid infection. During the cleaning up and debridement of the wound, he believes in changing drapes and instruments. He uses tetanus antitoxin routinely and also polyvalent antitoxin for gas gangrene.

Mock[41] believes that it is impossible to make any hard and fast rule regarding early closure associated with fractures. In some of his cases early closure is done while in others treatment is managed as for infected wounds, with delayed closure. However, most of these last granulate and heal without being sutured. He says that, from a practical standpoint, early closure of the wounds cannot well be carried out if the patient is suffering from shock. In such cases it would obviously be dangerous to attempt immediate debridement and closure.

Mock also feels that if the patient gets immediate first aid with proper splinting of the fracture and arrives at the hospital in good condition, there is a much better prospect for immediate closure from the standpoint of both shock and infection. On the contrary, in many instances where the patient is mishandled from the start, there is considerable delay before he receives any intelligent medical care and a large area of contamination is present, the situation is entirely different. He feels that from a practical standpoint it would probably be safer for the average man to leave the wound open. However, he has some doubt about the advisability of using a vaseline gauze pack and thinks it may add to the chances of infection in the wound. He favors secondary closure in some cases. In bad injuries the question of saving life must come first, and therefore debridement and closure may have to be delayed.

Emmett and Hawkins[42] have been practicing early debridement and closure for a number of years and find the method satisfactory in most instances.

Whitman[43] advocates and practices a modified Orr plan in dealing with compound fractures. If the wound has been made from within out, he debrides and sutures, but does insert a vaseline gauze drain and applies a cast which he does not remove or disturb unless there is an elevation of temperature persisting for more than five days. Ordinarily the gauze drain is removed through a window in the cast about the fourth week. In compound fractures in which the laceration of the soft tissues has been made from without, the wound is left more widely open and more extensively packed with vaseline gauze. If skeletal traction is used instead of a cast, a dressing is usually

applied over the wound. If mutilation of the soft tissue is extensive, Dakin's irrigation is used.

COMMENT

Some of the advantages of the primary closure method are as follows: First, the patient is saved in many instances a prolonged period of hospitalization, as well as the pain and inconvenience of frequent dressings. Second, the injured limb, after healing, is left in a much better condition; if the case turns out successfully, it is covered with relatively normal skin rather than a large area of scar tissue of low vitality that is prone to break down on slight provocation. Third, the loss of time and the expense of care can be kept down to a reasonable minimum.

Summing these advantages up: (1) the patient is often saved prolonged hospitalization and discomfort and expense; (2) the doctor is saved time utilized in applying numerous dressings; (3) the hospital is saved many patient days, much of the expense of prolonged hospitalization and the cost of many dressings; and last and most important (4) the injured part of the body is usually left in a much better condition, being covered with normal skin rather than with scar tissue of low vitality.

However, the technique can only be carried out successfully by a surgeon who has thorough training in this class of work. It requires a most scrupulous asepsis and meticulous attention to detail.

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DISCUSSION OF THE PAPERS OF DRS. ESTES AND CANNADAY

Mont R. Reid (Cincinnati): Before I make any comments on these two splendid papers, I want to express my appreciation for the privilege of attending and participating in this first meeting of the American Association for Traumatic Surgery, which I feel is going to be a very distinct contribution to surgery in this country. If it were possible. I am sure that the spirits of Paré and Billroth, of Sir Astley Cooper and Lord Lister would really rejoice at the formation of a society for the study of wounds. In a sense, I think a synonymous term for this Society might be the American Association for the Study and Treatment of Wounds.

After the work of Lister and the twenty-five years following that, when the fundamental principles of asepsis and antisepsis were being established, many people had the feeling that the problem of treating wounds had been solved. The men whom I mentioned felt that the proper treatment of wounds was the most important requirement of the surgeon. I feel that that is equally true today and that it is always going to be true so far as surgery is concerned.

Many surgeons have come to deplore the lack of interest during the past generation in this very fundamental problem, and I think that that feeling is responsible for the revival of interest in wound healing. An

unfortunate thing during this period of lack of interest in the treatment of wounds was that most of us became more or less the victims of routine and of the propaganda of the manufacturers of germicides which stressed the points that asepsis and antisepsis were the only important factors in wound healing. So I am extremely happy to be here on this occasion, because I feel that your society is going to be a great influence in revaluing all of the important factors involved in the problems of wound healing.

I said in the beginning that before I commented on these two excellent papers I wanted to make a few general remarks. Praise is now my only discussion, because I find no points of disagreement. I have enjoyed the papers tremendously, and I think they have stressed the fundamental principles of wound healing.

In Dr. Estes' paper he spoke of the methods of controlling hemorrhage in traumatic wounds, such as pressure with gauze. He does not resort to the use of a tourniquet unless it is necessary. To his advice I would like to add the simple expedient of elevating the wounded part. Often in the teaching of students, or even of interns who become excited in the management of a wound and put on a tourniquet to control the bleeding (often ineffectively if there are two bones at the site of the tourniquet), I make them look foolish by removing the tourniquet and holding the hand or foot straight up in the air and having the bleeding stop almost immediately. A great many doctors do not realize the value of an elevated position in the control of hemorrhage from wounds.

I think Dr. Estes has drawn attention to a very important point by warning us not to let our great zeal for cleaning and closing traumatic wounds be extended to certain wounds which should never be treated in that way. Certain wounds can certainly be so badly soiled that it is unwise surgical judgment to endeavor to close them even after the most meticulous cleansing and debridement.

That idea brings me to the discussion of another point. So many people have the idea that if a wound is not to be closed there may be a relaxation in the meticulousness of the toilet of such a wound. I feel that such ideas are very erroneous and that such practices can in no way be justified. A complicated wound which is not going to be closed deserves just as meticulous debridement, washing and cleansing, as does a wound that you are going to close. Theoretically, it deserves more, for it will not have the protection of a skin covering.

After that is done, it has been my general policy and feeling that such a wound should not be disturbed until the protection of granulation tissue forms in it. After all, lacking skin or mucous membrane, granulation tissue is the next best protection of any wound, and, personally, I think it usually forms most effectively when the wound is least disturbed.

I do not feel competent to discuss compound fractures. I think Dr. Cannaday has brought out some very excellent points and has also stressed the important fact that we should not let our enthusiasm run away with

judgment in our revival of interest in the cleansing and closing of compound fractures. Certain cases will be so badly soiled that no attempts at closure should be made even after the most careful debridement and cleansing.

He brought up one procedure which we have not used very much and that is the use of rongeurs to cut away dirt-stained periosteum and bone. We have felt that it was safer to use a very sharp chisel and a hammer rather than the rongeur, which often leaves fragments of bone and may grind dirt and organisms into the freshly cut surface of the bone.

I repeat again that I have enjoyed the privilege of listening to your papers and of participating in your meeting.

PHILIP H. KREUSCHER (Chicago): I was very happy to hear this paper and was particularly interested that facts were brought out which evidently had been lost in the last few years. So many of us have forgotten our experiences during the World War and the methods of treatment which were finally practiced during the latter part of the reconstruction period.

We all remember the thousands of men whose wounds became infected and have not forgotten the morbidity and mortality which followed these infections. The institution of the Carrel-Dakin method of treatment and their management of wounds revolutionized the treatment of sepsis and saved many thousands of extremities and many hundreds of lives. The results were so good that the surgical staff of the entire army of France, England and America expressed themselves satisfied with the fact that the discovery or the introduction of the Carrel-Dakin method of treatment was the greatest advance of wound healing since Lister and Pasteur.

We all began using the Carrel-Dakin method of treating wounds and became very enthusiastic for a time, but most of us discontinued its use because there was so much difficulty in preparing the solution, there seemed to be so much irritation of the wound and the interns and nurses, because of the more or less complicated method of management, grew tired in their efforts to carry it on. There are a few men who have never entirely discontinued this method. Among them is Dr. William O'Neill Sherman of Pittsburgh, who was the first to introduce it in this country and who spent many months with Carrel in France.

At the present time a great many of the objections to this method of treatment have been removed. Hypochloride, which is 4.05 per cent sodium hydrochloride, is now on the market and has been for years. One can simply take this solution and dilute it with seven parts of sterile hypotonic salt solution or with sterile distilled water, and it is ready for use. This solution is quite stable and can be kept for weeks in a dark container in a cool place without losing its efficacy.

For two and a half years I have used this method of treatment in a large number of cases. At the dressing stations in the steel corporation emergency hospitals we give approximately 12,000 treatments a month,

90 per cent of which are for acute wounds from abrasions, cuts, etc., and acute compound fractures.

The subject of careful preparation of the tissues around an open wound is very important. A great difficulty is to persuade the nurses and assistants that it is necessary to clean the surface of the skin around every wound and abrasion, that this must be done very thoroughly, and that it must include not only the shaving of the hairy surface but also a very thorough cleansing of otherwise normal skin.

Primary debridement of the wound itself, especially in cases with compound fractures or deep lacerating wounds, is very important. It is so well understood that it is not necessary for me to go into it any further. Several sets of instruments should be used in cases of this type, especially in the very dirty wounds.

I am glad to see that we are coming back to the rational treatment of wounds and that we are beginning again to make use of the things which science has placed into our hands rather than looking about for false gods.

W. L. Estes, Jr. (closing): I have nothing further to add except to thank both Dr. Reid and Dr. Kreuscher for their delightful discussion as they have brought out only too well the points that may have been glossed over in the paper.

John E. Cannaday (closing): I have nothing more to add except to express my appreciation for the illuminating discussion and to thank those who took part in it. I did mention the use of the chisel in debriding bone. I think it definitely has its place.

SURGICAL TREATMENT OF INJURIES OF THE CHEST

CASPER F. HEGNER, M.D.

DENVER, COLORADO

INJURIES to the thorax, to the viscera within and contiguous to its walls, are surgical problems for accurate diagnosis and adequate treatment.

Adequate treatment in a well equipped hospital with a completely organized competent, experienced surgical and nursing staff is vastly different from what is proper treatment for the same type of case in the country or in a small hospital with meager facilities and short handed personnel.

These are important factors which determine whether radical or conservative measures should be immediately invoked. Limitations imposed by a lack of personnel and facilities to cope with exigencies that might arise during treatment should govern the plan of procedure. The objective of any plan of treatment is to restore the altered conditions to as near their normal status as possible with the least added surgical trauma.

In the early period of the World War injuries to the thorax were attended by a high immediate mortality. Complications with later death or chronic invalidism was the rule in the cases which did not promptly succumb. During the later period with better organization of surgical personnel and hospital facilities two plans of treatment were devised, one by the British[1] and French[2] was radical; the other by the Italians[3] was conservative. From these plans, principles of and indications for surgical treatment of chest injuries were crystallized which greatly reduced mortality and complications.

Circumstances attending and the injuries sustained by the chest, in civil life differ greatly from those inflicted in war. The principles of treatment do not differ. Casualties in civil practice are usually multiple, those of the thorax commonly of the closed type. The extent of internal damage in closed injuries of the chest is more difficult to estimate than that in open chest injuries. They demand a high degree of surgical judgment in selecting the opportune time and proper procedure for their treatment.

Injuries of the thorax may be classified as:

- Closed
  - Contusion of the extrathoracic structures.
  - Contusion, compression of the thoracic wall; with or without direct or indirect fracture, dislocation of ribs, costal cartilages and sternum.
  - Contusion, laceration of the parietal or visceral pleura.
  - Contusion, compression of intrathoracic structures.
  - Laceration of the heart or great vessels, intra- or extrapericardially.
  - Contusion, compression of the lung, trachea, bronchi.
  - Contusion, laceration of the diaphragm, subdiaphragmatic, viscera the liver, spleen, kidney or stomach.
- Open
  - External
    - Laceration of extrathoracic structures to the pleura: Compound fracture of ribs, cartilage, sternum, with and without penetration of the parietal and visceral pleura.
    - Large or small direct open wound in the thoracic wall.
    - Laceration or perforation of the external wall, pleura, lung, bronchi, trachea, pericardium, heart, diaphragm and subdiaphragmatic viscera.
  - Internal
    - Contusion, rupture, laceration of lung, bronchi, trachea, mediastinum, diaphragm without an open defect in the thoracic wall.

The degree of damage depends on the character, direction, intensity and duration of the traumatizing force, the elasticity of the chest wall, ribs, cartilages and sternum, the nature and extent of the injury to the parietes, the type and location of trauma to the intrathoracic viscera, the mediastinum and its contents, the diaphragm and subdiaphragmatic viscera.

Injuries are more serious in the upper than in the lower thorax, more urgent the nearer the root of the lung. Injuries to the heart, the great vessels, trachea and mediastinum are most serious and frequently promptly fatal. In open chest wounds the gravity increases with the size of the opening and the length of time it remains patent.

Blunt traumatizing compressing force, especially on elastic chests of the young, can and often do cause extensive or fatal internal injuries without the slightest evidence of trauma to the superficial structures. The visible trauma to the thoracic wall is no index to the character or degree of intrathoracic damage.

Immediate collapse or sudden death may ensue from compression of the chest. This may be due to shock, vagosympathetic reflex, vascular paralysis, traumatic angina pectoris with acute cardiac insufficiency and consequent cerebral anemia.[4,5]

In cases surviving the immediate effects of trauma, there are the dangers of acute massive, continuing, recurrent or secondary intrathoracic hemorrhage, delayed rupture of the myocardium or great vessels, open, closed or tension pneumothorax, massive collapse of the lung, paradoxical interpulmonary breathing, emphysema of the mediastinum, extra- and intrapericardial tamponade, and the late hazards of infection; bronchopneumonia, traumatic pneumonitis, abscess, gangrene of the lung, empyema and cellulitis of the mediastinum.

The first examination of patients with chest injuries should be brief, gentle and as thorough as possible. Avoid all unnecessary moving and shifting of the patient. An increasing hyperresonance indicative of tension pneumothorax or a mounting dullness suggestive of intrapleural fluid should be promptly investigated by a diagnostic aspiration of the pleural cavity through a small gauge needle. This will give more reliable information with less discomfort and danger to the patient than prolonged, painful examination. During the first twenty-four to forty-eight hours the progress of the intrathoracic changes can be more accurately observed if the chest is not strapped with adhesive. An almost equal degree of immobilization and comfort can be secured by applying a firm wide chest binder without rolling or disturbing the patient. The binder can be conveniently opened and closed as often as reëxamination demands.

X-ray examination is indispensable. In the initial stage *x*-ray is not always conclusive as to the nature or extent of the damage. In the severely injured the moving and shifting necessary to secure proper exposures for reliable information increases shock and aggravates the damage already sustained. Fluoroscopy is more conclusive than *x*-ray films in the diagnosis of intrapericardial tamponade, the absence of expansile cardiac pulsation being pathognomonic. The most informative films are those taken in the upright or erect positions. The erect posture is inadvisable during the first twenty-four hours. Carefully elicited physical signs give sufficient information for early treatment in most patients who survive transportation and admission to the hospital.

Reaction to injury varies greatly with different individuals. The reaction is much more severe in those who have had previous pulmonary or cardiac lesions.

Pain is greater in parietal trauma than it is in much more serious visceral damage. The intensity of pain is no reliable index to the gravity of internal injuries.

Respiration in chest injuries is guarded. Inspiration is shallow and quiet, expiration forced and audible. Contractions of the diaphragm, painful splinting of the abdominal muscles and acute ileus especially in trauma of the lower thorax may lead to the erroneous diagnosis of subdiaphragmatic damage.

Dyspnea may be severe and immediate due to pain, irritation of the pleura, or aspiration of foreign bodies from the mouth, i.e., gum, tobacco, candy. Dyspnea from massive collapse of the lung in wide open pneumothorax is prompt, increasing in severity with the size of the open defect in the chest wall or large bronchus. Tension pneumothorax causes a progressive dyspnea. This progression is directly proportionate to the increase in intrapleural pressure and consequent mediastinal flapping and shift to opposite side. Other causes of dyspnea are anemia secondary to massive hemorrhage, waning cardiac capacity, cardiac tamponade, splanchnic vascular dilatation, acute ileus with distention of stomach and bowels. Late dyspnea is due to some added cardiac or pulmonary complication.

The pulse immediately after injury may be slow. Tachycardia with more or less irregularity is the rule. Immediate tachycardia is irritative or reflex in origin, has not the serious import of tachycardia due to cardiac injury, hemorrhage, tension pneumothorax or infection. This is to be remembered if radical measures are urgently indicated. An immediate rapid pulse per se should not cause delay.

Hemoptysis is a positive sign of lung injury. It is immediate and nearly always present in contusions of the lung. When early, profuse and continuous, it is indicative of a wound in or close to the main or a large bronchus. Hemoptysis is frequently delayed in penetrating and traversing wounds of the lung. This type of wound is nearly always accompanied by some degree of pneumothorax which may be and often is sufficient to promptly compress the wounded area of the lung and temporarily block its bronchotracheal communication. Hemoptysis may be absent in serious lung injuries accompanied by pneumothorax.

Traumatic pneumothorax may arise from an open wound in the parietal wall, in the lung or large bronchi. That from a small and promptly sealed external wound is slight and transient. It may be slow in developing and remain unrecognized for days. Pneumothorax is immediate and massive if the opening in the wall or bronchus is large and remains patent. It progressively increases in valvular types

of openings either in the lung or thoracic wall. A tension pneumothorax may rapidly develop to a grave or fatal degree. (Coughing, straining, restlessness, excitement, forced breathing aggravate the damage of the initial trauma and increase the degree of tension within the pleural space.)

In open pneumothorax (internal or external) air is sucked or forced through the wound into the pleural cavity during respiration. The suction acts with equal force on wounds and open vessels within the lung, favors continuance of hemorrhage and tends to dislodge clots sealing the vessels, leading to recurrent hemorrhage. The negative intrapleural pressure is also a factor in the development of transudates and the increase of exudates in the pleura.

Therapeutic pneumothorax eliminates the effect of suction, compresses wounds, vessels and bronchi, prevents hemorrhage and rests the lung, giving assurance of healing. In the absence of manometrically controlled air induction, the clinical signs of absence of respiratory murmurs on the injured side must be secured and maintained to assure an efficient degree of compression.

Hemothorax is an infallible sign of damage to the lung and pleura. Hemorrhage from rupture or laceration of the great vessels in the mediastinum or root of the lung is immediate, fulminating and massive. Early, slowly progressive or recurrent hemorrhage is increased by excursions of the lung. Hemorrhage from the periphery of the lung is moderate or small, may take hours or days before it becomes demonstrable. Existing pleuritic adhesions tethering the lung to the chest wall increase the volume and duration of hemothorax and interfere with the control of bleeding by preventing collapse and compression of the lung.

The volume of blood in a hemopneumothorax is in inverse ratio to the volume of air present. The amount and rapidity of bleeding are determined by the character of the traumatizing force, the caliber and location of the bleeding vessels, their relation to the free pleura, the motility of the site of the bleeding vessels, the influence thereon of the pumping action of the expanding and contracting diaphragm, chest wall and lung during respiration, and the time required for establishing a controlling degree of intrapleural positive pressure. The prompt induction of pneumothorax to control intrapleural bleeding is founded on sound physiologic and mechanical principles.

The blood in hemothorax clots slowly, partially or not at all. The causes are imperfectly understood. Clotting time is influenced by the rapidity of the bleeding. The slower the bleeding and the smaller

the volume of blood the less likely is clotting to occur. This interval favors precipitation of fibrin, permits tissue and pleural reaction to occur which modifies the blood and inhibits or prevents clotting. In massive acute hemothorax there is little or no time for pleural reaction and precipitation of fibrin. The blood clots and is absorbed slowly.

Blood in the pleural cavity changes in a short time. This time element is the basis for the diagnostic aspiration test for massive and recurrent bleeding wherein the blood nearly always coagulates.[6] It also explains why the blood is not altered in massive hemothorax and can safely be used early for autotransfusion.

The blood in a hemothorax may be rapidly absorbed at least in part. This partial absorption permits early reëxpansion of the lung, favors reopening of wounds and recurrence of hemorrhage. Early reëxpansion of the lung must be avoided. The first blood entering the pleural cavity in the formation of a hemothorax is sterile. That entering later may be contaminated with bacteria from the lung and bronchi. The presence of fluid or clotted blood in the pleural cavity is an ideal medium for bacterial growth. A moderate or small hemothorax is ample to sustain and propagate any contaminating bacteria. The possible contamination of continuing or recurrent hemorrhage emphasizes the advisability of aspirating all the blood and prevent recurrent bleeding by therapeutic pneumothorax.

Blood within the pleural cavity and the deposition of fibrin on the pleural surface inhibits whatever resistance to infection the pleura may possess. It excites a reaction pleuritis with the formation of plastic exudate and intractable adhesions. These must be prevented.

Pneumothorax will promptly control or stop bleeding from the mid-lung field or periphery. That from the vessels near or in the root of the lung is less effectively controlled. Bleeding from the parietal wall, particularly the intercostal or internal mammary vessels cannot be controlled by pneumothorax.

Fractional aspiration of blood is not so effective as complete aspiration and replacement with air. Introduction of air coincident with aspiration of the blood and fluid makes complete aspiration possible without the danger of unpleasant and occasionally serious reaction due to too sudden altered intrapleural pressure.

Fractional aspiration in some instances may be harmful. By permitting early reëxpansion and active movement of the lung, it favors continuing or recurrent bleeding and auto-infection of the pleural cavity. Fractional aspiration does not completely remove the

fertile media for bacterial growth. It does not eliminate the blood which in any amount inhibits the resistance power of the pleura. It does not prevent the deposition of plastic exudate and the formation of adhesions.

It is logical, as soon as the patient reacts from his injury, to aspirate as much of the blood from a hemothorax as possible and coincidently induce and maintain a manometrically controlled pneumothorax. In the absence of a pressure manometer the volume of the replacing air should exceed by 200 or 300 c.c. the volume of the fluid aspirated or air should be replaced until signs of respiratory murmurs in the lung disappear and the injured lung becomes silent.

Inducing and maintaining complete air replacement secures collapse of the lung, compresses wounds, closes bleeding vessels and open bronchi, the commonest source of infection, eliminates the media for bacterial growth, prevents the formation of plastic exudate and tethering adhesions,[7] reduces reaction pleuritis and inflammatory processes in the lung, rests the lung and favors healing.

Blood or fluid of any kind does compress the lung. Fluid is inelastic, non-compressible, and does not accommodate itself to the volumetric changes of the lung during respiration. Air of less than atmospheric pressure is elastic, diffusible, compressible, follows the slightest movement of the lung making for constant uniform compression and efficient immobilization. Air does not embarrass to the same degree as fluid the retractible power of the opposite lung.[7] Manometrically graded pneumothorax is ideal for controlling all factors of injuries to the lung which do not urgently demand radical measures. The earlier it is induced, the more effective.

Compression injuries of the heart are usual sequences of blunt trauma to the chest. (The position of the heart between the sternum and spine make it susceptible to injury by compression.) The symptoms may be mild and transient, moderate, lasting for hours; severe, persisting for days or months; fatal resulting in immediate or delayed death. There may be no external or superficial evidence of injury yet the cardiac damage may be permanent or fatal. Postmortem findings of cardiac compression in immediately fatal cases may be inconclusive or absent. Those in delayed or late deaths show positive evidence of coronary and myocardial pathology, ecchymosis, focal hemorrhage, pericarditis, epicarditis, myocardial fibrosis.

Symptoms may be those common to shock—syncope, pallor, an imperceptible, small, slow or rapid, intermittent, irregular pulse. Electrocardiogram indicates disturbance of conduction. The arterial blood pressure falls, the venous pressure rises, heart sounds are faint.

The symptoms are reflex in nature. The reflex may originate from the surface of the body or from the viscera and is reflected over the sympathetic and central nervous systems, affecting the heart, the peripheral, cerebral and splanchnic vessels.

In severe compression, pain in the cardiac area may be sharp and lasting. There may be a true traumatic angina pectoris with contraction of the coronary vessels, acute myocardial ischemia, cardiac embarrassment, dilatation and a cerebral anemia. If this lasts long enough, myocardial damage with all the characteristics of coronary block, fibrosis, scarring, thinning of the wall, local aneurysmal dilatation, and cardiac decompensation[8,9,10] will develop. These pathologic changes emphasize the importance of rest and obligate a guarded prognosis during the first weeks following compression of the chest with severe or persistent cardiac symptoms.

Fracture of the ribs may be single, multiple, comminuted or compound. Such a fracture can usually be recognized without moving the patient. Fractures of the sternum and cartilages, unless marked deformity is present, are difficult to diagnose even with the *x*-ray. The clinical signs of point tenderness (which is difficult to elicit in the upper four ribs posteriorly) and pain on pressure in a fixed area warrants the diagnosis. Complex and comminuted fracture of a rib or ribs is more dangerous since the fractured ends and bone spicules commonly cause puncture, laceration or other injury to the pleura and lung. Fracture of a single rib due to blunt trauma rarely causes hemorrhage from the intercostal vessels.

Fractured ribs may have little influence on the intrathoracic function unless accompanied by intrathoracic damage. The reverse is true in penetrating wounds especially, shot and stab wounds, in which the internal damage is always greater than the external evidence indicates. The damage to the chest wall in closed injuries is not so hazardous as that sustained by the contained viscera: contusion, rupture of the heart, contusion laceration of the lung and pleura, hemopneumothorax. Internal damage must be looked for by frequent recheck examination. The chest should not be strapped with adhesive, especially in upper thoracic wall injuries. Strapping may aggravate the damage, and interferes with reëxamination and observation of the course of intrathoracic injury.

Emphysema may be subcutaneous, subpleural or mediastinal; local, spreading or generalized.

Localized subcutaneous emphysema occurs in valvular or oblique wounds in the extrathoracic structures, the air being sucked in and spread by muscular contractions and movement.

Spreading emphysema may develop in open or closed wounds communicating with the pleural space and punctured and lacerated wounds of the lung. The air from within the chest is forced into the subcutaneous tissues more rapidly than it can escape through the opening in the skin. It is most frequent and more generalized in wounds of the lung and bronchi which are held by adhesions in open communication with the subcutaneous tissues, the overlying skin being intact. The larger and more direct this opening, the more extensive and rapid the development of emphysema. It usually develops promptly, spreads rapidly throughout the loose cellular tissue of the neck, face, trunk and extremities.

Coughing, straining, labored breathing, and muscular effort raise the intrathoracic pressure, increase the escape, accumulation and spread of air in the cellular tissues.

Subcutaneous emphysema is not dangerous, but the underlying injuries may be very serious. If escape of air cannot be controlled at the opening in the lung or chest wall, needle the pleura to determine the presence and degree of tension pneumothorax. It may be possible to reduce and control the intrapleural tension and stop the subcutaneous escape of air.

Mediastinal emphysema is most frequent in severe compression of the chest with no open external wound. It may complicate wounds at the base of the neck, operations for substernal and intrathoracic goiter, retraction of the bronchial stump after lobectomy or pneumonectomy. Mediastinal emphysema develops and spreads rapidly and may attain a high degree of tension.

The symptoms depend on the rate, amount and pressure of the air accumulating in the mediastinum. There is progressive dyspnea, cyanosis, bilateral venous congestion in the lungs, dilatation of veins in the neck and upper chest, pain dysphagia, extra pericardial pneumatic tamponade, circulatory failure and death. Physical signs first appear in the jugulum and base of the neck as a soft crackling swelling which rapidly extends up the neck to the face and head, into the axillae, down the arms, chest and abdomen. There is tympany over the entire sternum, breath sounds are reduced. Heart dullness is obliterated, the heart sounds become progressively fainter. There are crackling râles synchronous with the heart beat. Small amounts of air may be overlooked. *X*-ray films show mottled areas with vertical columns of decreased mediastinal density. The large vessels are well differentiated.[11]

The treatment is transverse incision over the jugulum, cutting the attachment of the strap muscles to the sternum, and the insti-

tution of cup or suction drainage. If the condition is not promptly relieved the mediastinum is opened parasternally or the sternum split.

GENERAL OUTLINE OF TREATMENT

Closed Wounds. Treat shock, prevent or control hemorrhage, cardiac and respiratory embarrassment. Morphia is given in sufficient dose to assuage pain, to slow and quiet respiration, to reduce anxiety and restlessness. Small doses repeated at short intervals are better than large doses at long intervals. Oxygen inhalation is necessary for dyspnea, and graded transfusions to restore and maintain the circulating media. Blood is better than solutions of glucose or acacia in such transfusions.

In a careful general physical examination, note the gross intrathoracic and circulatory status, moving the patient as little as possible. Check the progress by reëxamination until the patient begins to improve. For immobilizing the chest wall apply a snug binder rather than adhesive straps, and thereby avoid moving and rolling the patient, and obscuring physical signs.

Reduce tension pneumothorax and maintain a comfortable degree of compression by repeated needle aspiration or a small indwelling trocar, with a connected water valve trapped tube.

In hemothorax, carry out early aspiration of all the blood possible, using it for direct autotransfusion if hemorrhage is massive.[12,13] Replace the volume of blood aspirated with a slightly greater volume (200 to 300 c.c.) of air. Check the intrapleural pressure manometrically.

Fluoroscopy and roentgenography are necessary as soon as possible after reaction from shock.

Direct surgical attack for intrathoracic cardiac and subdiaphragmatic damage is at times urgently demanded. To cope successfully with these, especially in injuries of the closed type, taxes the judgment and ingenuity of the most versatile surgeon. Surgical attack for injuries to the heart, the great vessels at the base, in or near the root of the lung or in the mediastinum is imperative and most formidable. Open radical operations are reserved for progressive uncontrollable hemorrhage, mechanical respiratory and cardiac embarrassment, mediastinal emphysema, wide open defects in the thoracic wall, laceration of the lung, puncture of the heart, laceration rupture of the diaphragm and subdiaphragmatic viscera.

General anesthesia is used intratracheally or with a positive pressure mask.

For upper chest damage the approach is through the periosteal bed of the resected fourth rib; for mid or lower thoracic exploration, through the periosteal bed of the resected seventh rib. Additional ribs are cut anteriorly or posteriorly to enlarge the opening if required for thorough inspection and workable space. A pliable curved or angled rubber guarded clamp is applied to or a rubber tourniquet applied around the root of the lung to control bleeding. Foaming areas or points indicate the site of wounds in the lung. Bleeding is arrested by ligating vessels separately or by mass mattress suture. Damaged tissue is excised, foreign bodies removed, the lung sutured and inflated to test the sutures and determine the presence of any bleeding vessels. The surgeon explores for a rent in the diaphragm, removes all clots and blood, flushes the pleura, and sutures the periosteal incision. Tension on the suture line is relaxed by coapting the rib above and below with approximating sutures, closing the wound in layers as airtight as possible and injecting air into the pleural cavity to a mildly compressing degree. Postoperative repeated aspiration of accumulated fluid is necessary, accompanied by air replacement. If imperative later, a dependent counterdrain may be inserted by the closed method.

Open Wounds. Large defects in the thoracic wall must be immediately occluded and sealed. One may use the flat of the hand, a folded wet towel or cloth, cellophane, or rubber dam or one may insert a large moist soft gauze tampon, or pull the deflated lung into and block the opening. This temporarily controls the sudden massive collapse, steadies the mediastinum, and relieves cardiac and respiratory embarrassment. Immediate operation is then done under positive pressure anesthesia. The wounds and pleura are cleansed and closed and the lung compressed. The wound is debrided, fragments of comminuted ribs removed as well as all non-viable tissue and tags, all clots and blood. Bleeding vessels in the wall and lung are ligated, as are open bronchi. The lung is sutured and the pleural cavity flushed. The wound is closed, if possible, airtight. The lung is rested, sealed and healed by a mildly compressing degree of pneumothorax. If fluid accumulates, one must aspirate repeatedly and if and when pus develops, drainage by the closed method is done.

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DISCUSSION

JAMES M. WINFIELD (Detroit): It was a great pleasure to have heard Dr. Hegner's excellent paper.

The indications for aspiration of blood and replacement by air in those cases where there has been profuse intrapleural bleeding have concerned us greatly in the past year. We therefore chose a group of forty selected wounds of the chest which were penetrating in type. There were no complicating injuries of any moment. So far as we know, only the lung was involved, the great vessels and the heart escaping injury.

We divided these cases into those that had hemothorax, hemopneumothorax, and pneumothorax, and also as to whether they had a slight, moderate, or severe clinical reaction. The average number of days and the spread of days of hospitalization were listed for each type of case. When hemothorax alone was present, and a slight clinical reaction, the average number of days in the hospital was six, with a spread of four to eight days. When there was moderate clinical reaction, the average number of days in the hospital was eight with a spread of eight to ten days, and when there was a severe clinical reaction, the average number of days in the hospital was eighteen, with a spread of thirteen to thirty-three days. When hemopneumothorax was present, those cases with slight clinical reaction had an average number of days in the hospital of seven (three to fourteen). With moderate clinical reaction, the average number of days in the hospital was seven, with a spread of six to fifteen days; with severe clinical reaction, the average number of days in the hospital was nineteen, with a spread of fourteen to twenty-eight.

When pneumothorax alone was present, the patients exhibited only slight to moderate clinical reactions, and the average days in the hospital were five or six with a spread of three to eight. In comparing the three types of cases, it will be found that those patients exhibiting hemothorax and hemopneumothorax practically parallel each other in reactions and in

the number of days that they remain in the hospital. Those patients having pneumothorax alone had markedly less clinical reaction and their stay in the hospital was much shorter than those of the other two groups. It therefore seems that the important element as far as determining the reaction and morbidity is concerned, is the presence of blood in the pleural cavity. Also it seems evident that the greater the amount of blood, the more severe the reaction and the longer the stay in the hospital.

In only three of these cases was blood aspirated from the pleural cavity, with air replacement. One of these was a tension pneumothorax, and two had a rapidly increasing amount of blood with severe respiratory difficulty.

Possibly it would have been wise if we had aspirated the blood from the pleural cavity in a larger number of these cases, as this procedure might have lessened the patient's clinical reaction and shortened the patient's morbidity and stay in the hospital. It would be extremely interesting to me to know whether Dr. Hegner has any information regarding this particular point, that is, whether he has a more or less parallel series of cases and whether he found that the procedure of aspiration and replacement by air gave better results.

Hugh H. Trout (Roanoke, Virginia): Dr. Hegner referred to chest injuries in the late War. He stressed that there was a difference in the types of hospitals in which these patients received attention. I would like to add there was also a very marked difference in the type of patient we treated then and the patient we now treat.

During the World War Dr. Yates of Milwaukee and his associates operated on a great many more puncture wounds of the chest than the rest of us did. The rest of the group treated them "conservatively." Dr. Yates' immediate mortality was higher than our mortality. However, in going over those cases for a period of ten years after the War his mortality was lower than ours, for a great many of our patients died later from lung abscesses, general sepsis, etc.

I know of nothing that is more distressing to both the patient and the surgeon than to have the patient plastered up with a lot of adhesive straps. We bind our chest cases with a many tailed bandage which can be easily removed or tightened as indicated.

Immediately upon admission to the hospital, if it is possible to take an *x*-ray picture with a portable machine without disturbing the patient too much, this is done, not because the information obtained is of any great value, but to have the plate as a check for future *x*-ray studies. With the majority of cases no more can be done with the *x*-ray for a few days until the patient is able to stand in an erect position. Of course, the fluoroscopic examination of the chest is of more importance than any number of *x*-ray plates.

The complete and immediate removal of blood from within the pleural cavity with replacement of air is, I think, probably the greatest advance

in the conservative treatment of puncture wounds of the chest. It is a great pity that the manometer is not used more frequently, for it not only makes the replacement of air more scientific, but gives far greater comfort to the patient. Various fluids and antiseptics have been tried over the years, but air is far preferable for the replacement medium. If you do not have a manometer, 200 or 300 c.c. more air than removed fluid should be injected. We have never used the blood removed for autotransfusion, for even in early cases I think there is always too much danger of clots, infections, etc. We believe it is important to use small and frequently repeated doses of morphia rather than few large doses.

If anesthesia is necessary it should be given by the intratracheal measure or at least by a positive pressure apparatus.

In a few cases we have used sulfanilamide both by mouth and directly on the wound. I do not know whether it has been of any value or not, but in any case the administration of this drug should be checked by blood examination and close clinical observation. Our general rules are: (1) to operate on all sucking wounds; (2) to explore all puncture wounds near the sternal border; (3) to operate in all cases where the lung presents itself into the wound; (4) to operate where the diaphragm might be injured; (5) to intervene where there is a tense pneumothorax or (6) where there is marked subcutaneous emphysema.

Of course, very frequently, in injuries of the chest, consideration will have to be given to the treatment of injuries in other parts of the body. Recently we have seen a few cases of thoracic hernia coming through the chest wall. Some of these required operation. As a rule, the opening can be closed by osteoplastic flaps, though in two cases we have been forced to employ fascia taken from the fascia lata.

I want to again express my personal appreciation to Dr. Hegner for this well considered and timely paper.

Casper Hegner (closing): The wounds of the chest that I tried to emphasize were not stab wounds or gunshot wounds. We know, of course, that infection in those is not nearly so great as where we have tissue trauma of the chest wall or of the lung. The amount of hemorrhage in the lung and in the pleura, as I said, is important, and it is a source of irritation. It does not compress as well as air. Therefore, as soon as the patient recovers from shock, I believe as much blood as possible should be aspirated and this should be replaced immediately by air. This shortens the reaction time; shortens the stay in the hospital; gives better visualization in the *x*-ray. In addition, you can control the initial hemorrhage, you can control recurrent hemorrhage and you can prevent secondary hemorrhage as well as infection.

THE MISUSE OF SKELETAL TRACTION*

CARLETON MATHEWSON, JR., M.D.

SAN FRANCISCO, CALIFORNIA

SKELETAL traction, long considered feasible in the minds of surgeons, had to await the introduction of aseptic surgery for its safe and fullest application. As early as 1900 Heineke[1] described a method of applying tongs to the calcaneus. In 1903 Codivilla[2] introduced the use of the nail or pin, a method which in 1907 was elaborated and popularized by Steinmann.[3] In 1912 Klapp[4] improvised a method of direct traction on the calcaneus by the use of flexible wire which was threaded through the plantar surface of the heel in order to avoid pressure on soft tissues. During the world war Herzberg[5] improved this method when he devised a means of keeping flexible wire taut. All of these forms of skeletal traction, because of the dangers associated with their use, were not generally accepted until 1927 when Kirschner[6] described a simplified means of using stainless steel wire of 1 mm. diameter as a drill in itself.

Since that time there has been a growing wave of enthusiasm for the use of all types of skeletal traction. In the wake of this enthusiasm we find a number of complications, which have led to criticism of a method which is useful and sound when properly applied. The medical literature of the last ten years is filled with suggestions for the application of skeletal traction to the treatment of almost every known fracture. Some of these have considerable merit, but are often unwarranted substitutes for older, established methods. Some surgeons have lost sight of the fact that every wire, tong or nail inserted into bone constitutes virtually a compound injury to that bone, and carries with it the hazards associated with that type of injury. Enthusiasts have sponsored the use of multiple pins and, in certain fractures, the insertion of pins directly through the line of fracture. These methods, in the hands of experts, may lead to gratifying results, whereas their general use may result in nothing but disappointment.

The rules governing the application of skeletal traction as well as the indications for its use have been set down by many competent authors and will therefore not be repeated here except to

* From the Stanford University Surgical Service, San Francisco Hospital, Unit of San Francisco Department of Public Health.

mention that it is our conviction that the misuse of the method rather than the method itself leads to most of the difficulties associated with it.

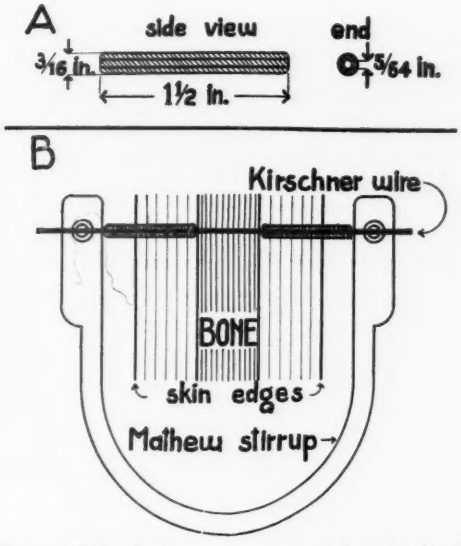


FIG. 1. Metal sleeve to prevent longitudinal axis motion of skeletal pins. A, dimensions of sleeve. B, sleeves in place. (Courtesy of Dr. Bret Smart.)

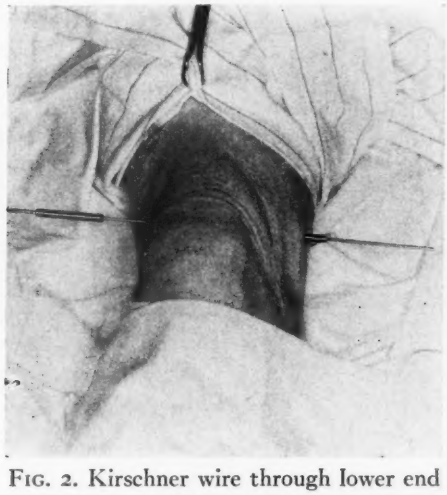


FIG. 2. Kirschner wire through lower end of femur with metal sleeves being placed. (Courtesy of Dr. Bret Smart.)

INFECTION

The greatest hazard associated with the introduction of metal into bone through the soft parts is that of infection. Infection may occur in the skin, in the underlying soft tissues or in the bone itself.

As a general rule it starts in the skin and extends by continuity into the bone. This, however, is not always so. Bacteria may be carried directly into the bone by the introduction of the metal

FIG. 3. Metal sleeves in place over Kirschner wire through ulna. (Courtesy of Dr. Bret Smart.)

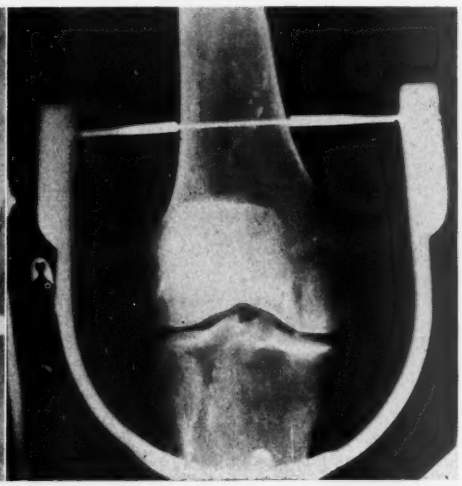
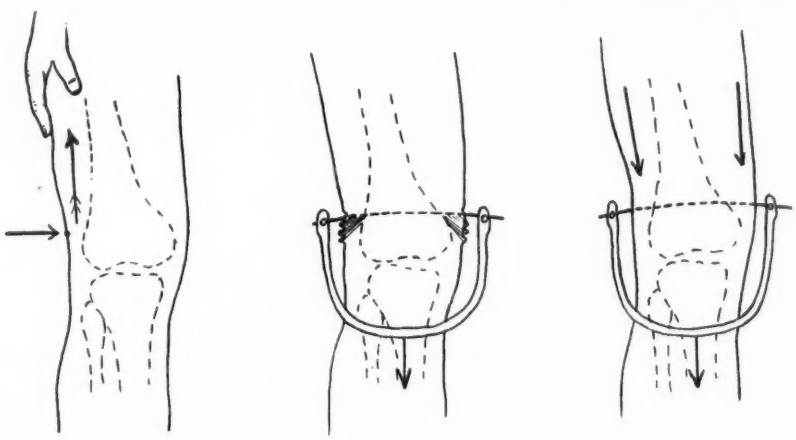


FIG. 4. Roentgenogram illustrating metal sleeves in place. (Courtesy of Dr. Bret Smart.)

agent through improperly prepared skin. Many surgeons take no other precaution than to swab the skin at the point of introduction



A B C

FIG. 5. Diagram: A, direction in which skin should be pulled before inserting traction pin. B, area of skin necrosis if skin is not properly treated. C, same when properly treated.

with a disinfecting agent. This is often the first link in the chain of misfortune that will follow its general adoption. Too frequently the insertion of a pin is treated as a minor surgical procedure with the

FIG. 6. Arrows indicate ring sequestra of cortical bone following removal of traction pin.

FIG. 7. Arrow indicates area of pressure necrosis in bone following skeletal traction. Note that wire has pulled out of bone into the soft tissues.

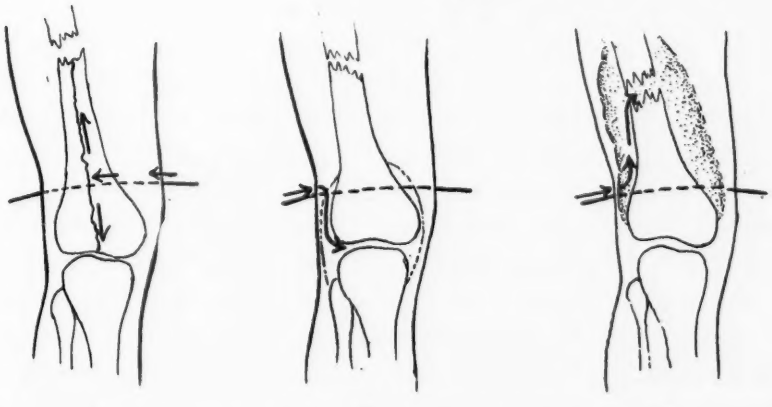


FIG. 8. Skeletal pin inserted through A, linear fracture communicating with the major fracture site and joint; B, a joint capsule; C, a hematoma which originates at the fracture site. Arrows indicate the course taken by invading bacteria.

patient in bed. The propriety of meticulous surgical technique cannot be over-emphasized.

Once the pin is inserted it must be fixed in place. Subsequent

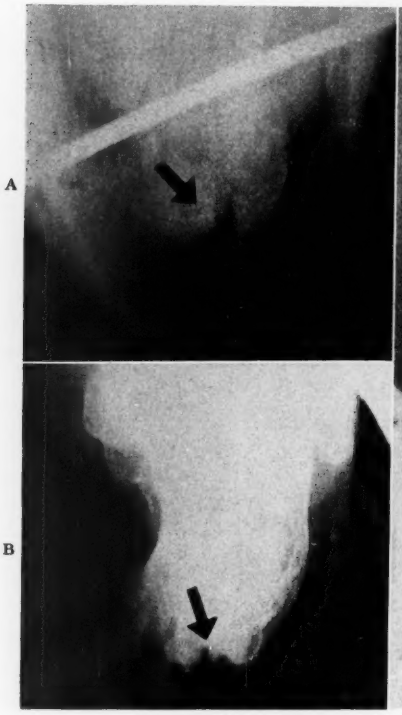


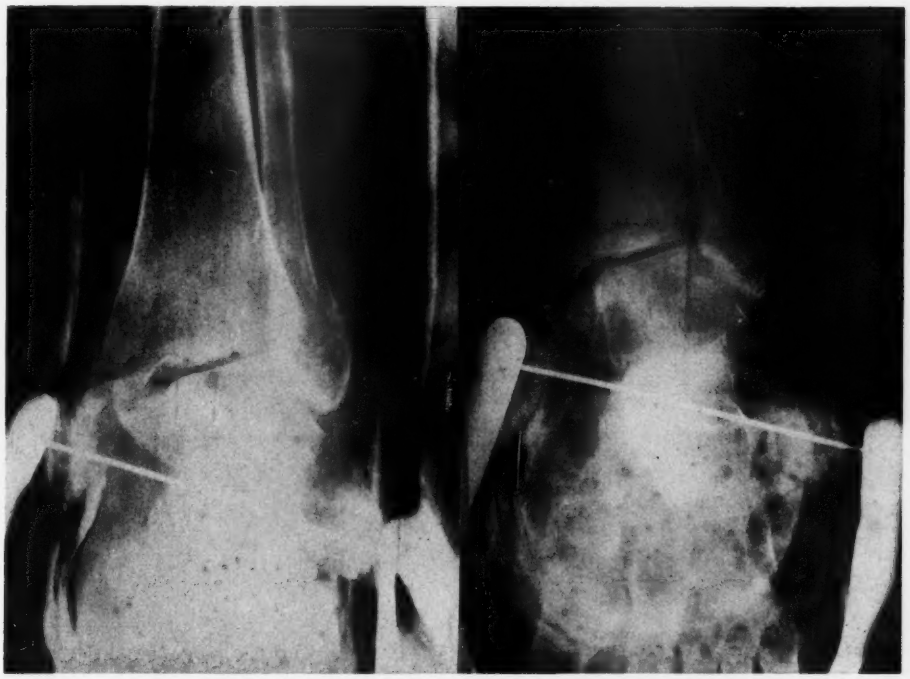
FIG. 9. A, skeletal pin through a linear fracture in os calcis. B, resultant osteomyelitis of os calcis.

FIG. 10. Gangrene of thumb following skeletal traction through terminal phalanx.

motion of the pin, particularly along the axis on which it was driven, will inevitably lead to infection. The consequences of this infection may or may not be great but it must be avoided at all costs. Motion in this direction is not apt to occur immediately after the pin has been inserted, because at first it is firmly embedded in the bone. Later, as traction is applied, aseptic pressure necrosis takes place in the bone, which allows the pin to become loose. Movement of the patient thereafter displaces the pin in its longitudinal axis so that the contaminated portion protruding from the skin slides into the subcutaneous tissues, carrying bacteria with it. This misfortune, as will be mentioned later, may lead to dire results.

Recognition of this danger has led to various means of prevention. Many surgeons insist upon using Steinmann pins rather than wire for this reason alone. It is true that Steinmann pins become fixed more firmly in bone, but they too loosen with time. When they

do they are more apt to cause trouble than finer wire because their initial damage to the bone is greater. Some operators depend upon material such as cork, rubber sponges or wrappings of gauze inserted



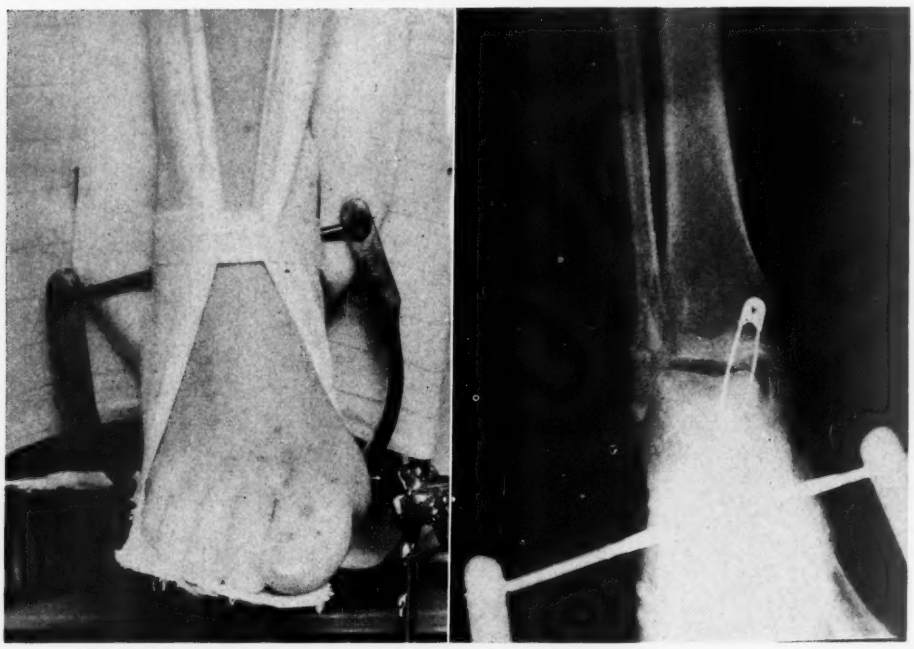
A B

FIG. 11. A, skeletal pin through os calcis at improper angle. B, sliding of pin with resultant pressure on soft tissues.

between the skin and the spreader to prevent longitudinal axis motion of the pin. All of these agents are, to a certain degree, unsatisfactory: some are too soft and allow a certain amount of motion; others are too hard, and cause pressure necrosis of the skin.

Recently we have been using the metal sleeves shown in Figures 1 to 4. These sleeves are made in varying lengths so that they fit firmly between the cortex of the bone and the spreader. After the wire is inserted into the bone the sleeves, one on each side, are forced along the course of the wire firmly against the surface of the bone through small incisions in the skin at the points of exit of the wire. The spreader or stirrup is then fixed firmly against the outer limits of the sleeve, preventing any motion in the longitudinal axis of the wire. The same motion also can be prevented by encasing the pin in plaster of Paris, provided there is no space left between the skin surface and the plaster encasement. It is a mistake to place bulky dressings over the openings in the skin under plaster. We prefer

to use no dressing at all. The dried-up secretions around the junction of the pin and the skin surface will prevent the invasion of the soft tissues with bacteria.



A B

FIG. 12. A, skeletal pin placed at improper angle. B, roentgenogram of same case.

Proper asepsis and fixation of the pin alone will not necessarily prevent infection. Once traction is applied the pull exerts itself, not only on the bone but also on the soft tissue in contact with the traction pin. Unless these tissues are freely movable, traction upon them will cause pressure necrosis and subsequent secondary infection. The amount of necrosis depends upon the resistance of the soft tissues to the force applied, and may be prevented by pulling them in the opposite direction to the expected line of pull at the time of insertion of the traction pin. (Fig. 5.) Allowance also should be made for a certain amount of bowing in the metal agent used for traction. The soft tissues in the region of a pin used for counter-traction must be similarly treated, keeping in mind the anticipated direction of pull.

Infection starting in the soft tissues may remain localized in the skin or subcutaneous tissues or it may extend along the course of the pin into the transfixed bone. Once the infection has reached the bone it may confine itself to the osseous tissue immediately in

contact with the pin or may spread to the medulla with a consequent widespread osteomyelitis.

If the infection is mild and the pin remains fixed in position the

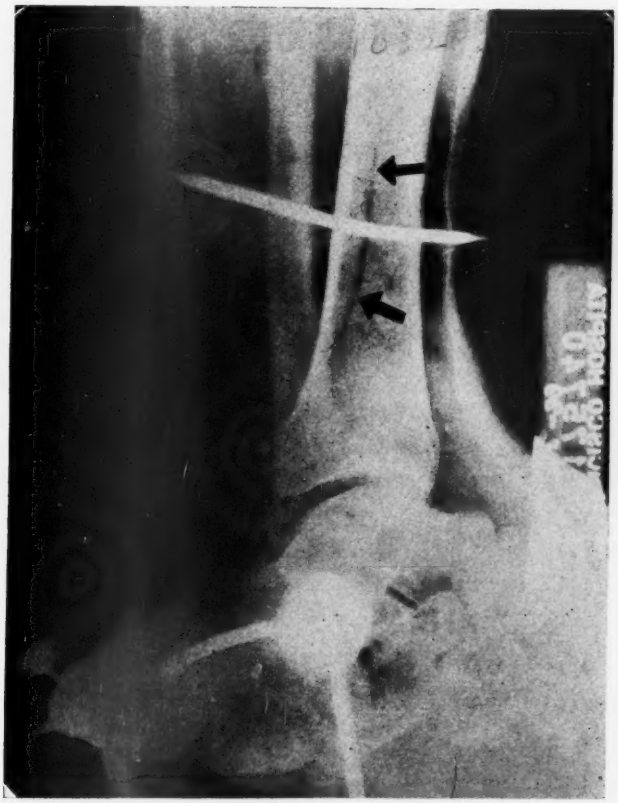


FIG. 13. Bone split by insertion of skeletal pin.

final outcome is apt to be a so-called "ring sequestration" of the cortical bone, as seen in Figure 6. These sequestra are often the cause of persistent draining sinuses. On the other hand, motion of the pin in the presence of infection will lead to more or less extensive bone damage. Constant traction under these conditions may result in migration of the pin out of the bone into the surrounding soft tissues or through damaged bone into a nearby joint or epiphyseal area. (Fig. 7.) Accidents of this type, in addition to causing prolonged suppuration, may result in disturbances of bone growth, destruction of joints and even loss of limb and life.

Not infrequently hematomata resulting from local trauma or spreading from the site of fracture are unwittingly traversed by the traction pin. (Fig. 8.) It is well known that hematomata offer the best possible conditions for the growth of bacteria, regardless of their number or virulence. Infection originating in this fashion will

extend, not only to the soft parts invaded by the hematoma but by direct continuity to the fracture site. As Kellogg Speed[7] has pointed out, "The surgeon must recall that the hematoma may

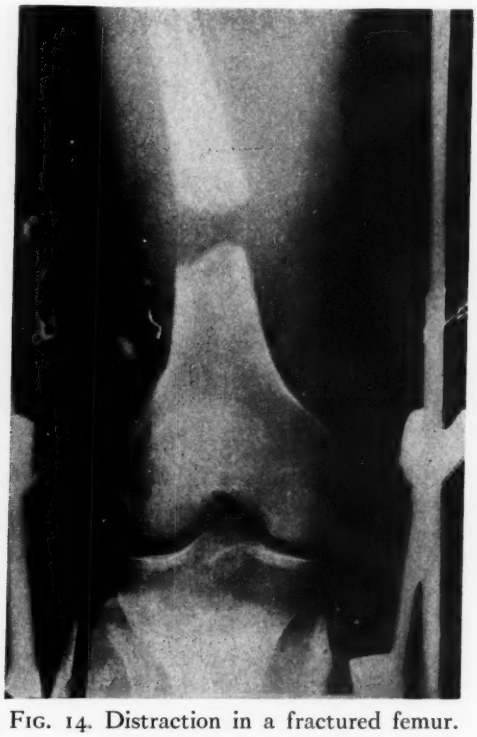


FIG. 14. Distraction in a fractured femur.

extend from one end of the limb to the other and even beyond some of the larger joints in severe injuries." Not infrequently a joint capsule or a bursa communicating with it are penetrated. Joints and bursae, as well as hematomata, offer excellent culture media for the growth of bacteria. Similarly, and in our experience more frequently, unrecognized linear fractures extending in the longitudinal axis of the bone from a major fracture site are traversed. (Fig. 8.)

Infection originating in the skin may extend along the course of the pin into the linear fracture line and then find its way to the major fracture. (Fig. 9.) In the past year we have seen empyema of the knee joint in two patients, both with fractures of the femur, treated with skeletal traction. In each of these patients there was an unrecognized linear fracture extending from a transverse supracondylar fracture into the knee joint. Both patients had a Kirschner wire driven through the lower end of the femur at some distance from the transverse fracture but directly through the linear fracture which communicated in each case with the knee joint.

Injuries to nerves and blood vessels either from penetration by the metal agent at the time of introduction or by subsequent pressure or infection may lead to permanent damage in the limb.

FIG. 15. Distraction in tibia and fibula.

Figure 10 shows gangrene of the thumb which followed the penetration of blood vessels by a metal agent inserted through the terminal phalanx.

ATTENTION TO DETAILS

Improper attention to details often leads to disaster in the use of skeletal traction. As a general rule, it may be stated that pins should pass through the bone at a right angle to the anticipated line of pull. The surgeon must be fully cognizant of what that line of pull should be before inserting the pin. Not infrequently a pin is inserted with the limb lying in the uncorrected position so that after the correct alignment is obtained the pin is found to pass at an unsatisfactory angle through the bone. This not only leads to inefficient traction but causes the pin to slide through the bone on its longitudinal axis. This, in turn may lead to infection or pressure necrosis of the soft tissues as seen in Figure 11. This is most apt to occur in injuries about the ankle joint where the os calcis is used as the point of skeletal attachment. Inversion or eversion of the foot tends to

FIG. 16. A and B, rotatory displacement in tibia maintained by skeletal fixation. C, nonunion after six months. C, nonunion after eight months. Note that fibula has united.

mislead the surgeon as to the proper angle at which the traction pin should be placed. (Fig. 12.)

Unintelligent selection of the type of metal agent to be used as

FIG. 17. Displacement of tibia maintained by fibula. Arrows indicate ring sequestra and linear fractures.

well as poor condition of the apparatus may result in trouble. Too large or too dull a pin may split the bone into which it is driven. (Fig. 13.) Pins which have been boiled too frequently lose their tensile strength and will bend under heavy traction. Bending may make it extremely difficult to remove the pin without undue damage to the bone or may cause splitting. We recall one patient in whom the femur was split through its entire length as the result of bending of a Steinmann pin under heavy traction.

The criteria for selection of the metal agent to be used for traction in various types of fractures, although of great importance, cannot be discussed here. Usually the danger of damage to the bone and of infection is directly proportional to the size of the metal agent used.

Likewise a discussion of metal tongs has been omitted. They are a useful device, particularly for skeletal traction on the skull in fractures of the cervical spine. Elsewhere they are extremely danger-

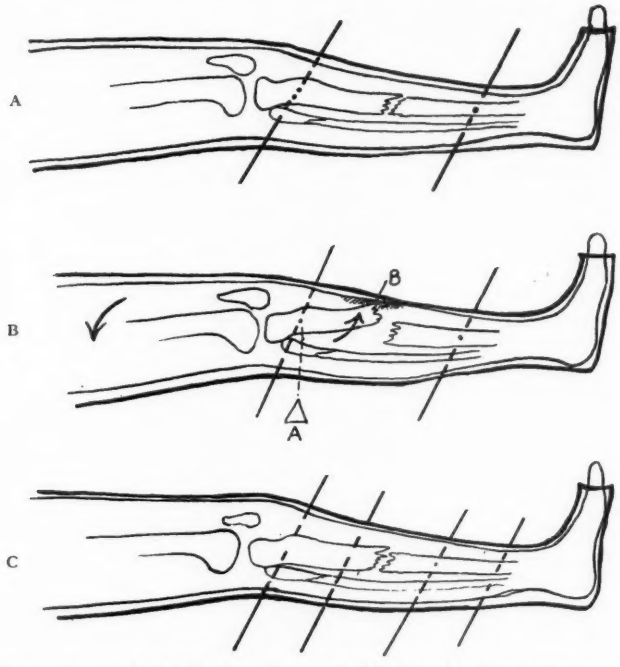


FIG. 18. A, skeletal pins above and below fracture site. B, rotation of upper fragment at point *A* as a fulcrum causing pressure necrosis at point *B*. C, multiple pins to prevent such rotation. This method is condemned by the author.

ous, even in the hands of experts, because of their tendency to slip, causing extensive and severe damage to the soft tissues.

DISTRACTION

Aside from infection, probably the greatest danger associated with skeletal traction is that of distraction, leading to delayed union or nonunion. Skeletal traction has provided the surgeon with an exceedingly efficient means of direct pull on the skeleton which, because of its inherent power, may prove disastrous. Too much weight or the use of an appropriate weight over too long a period of time will not only distract fragments but will stretch the musculature to the point that it loses its power to contract. (Figs. 14 and 15.) Prolonged distraction may be as difficult to correct as prolonged shortening. Distraction, if recognized early, can usually be corrected by decreasing the amount of pull, if during the period of

distraction soft parts or periosteum have not become interposed between the bone ends.

Frequent *x*-ray examination is of value to check the amount of

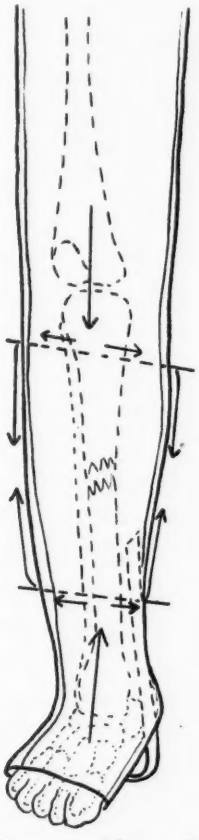


FIG. 19. Lines of weight bearing when two pins are incorporated in a walking cast. Note that there is no weight bearing on the fracture site.

pull but should not be the only means of control. Roentgenograms, unless taken in exactly the right plane, give an erroneous picture of conditions as they actually exist. Excellent reduction and alignment reported from the *x*-ray laboratory mean very little unless the clinical findings corroborate this statement. Bony crepitus felt at the site of fracture assures one that there is no interposition of soft parts and that the bone ends are in contact far more certainly than the *x*-ray picture.

A multitude of methods for the application of skeletal traction with single or multiple sites of skeletal attachment are now in general use. Most of the methods using a single point of skeletal fixation with continuous traction and suspension, although they present the hazards already mentioned, are comparatively safe, and in the treatment of certain fractures indispensable. The addition of secondary points of skeletal fixation to permit countertraction or pull and the use of distraction apparatus greatly increase the hazards. It would not be fair to condemn these modifications when exercised by experts. Nevertheless, a word of warning to the inexperienced is in order. In theory it is simple to pull, twist or angulate the fragments of a fracture back into place by mechanical means, using two or more points of skeletal attachment. In practice it is, unfortunately, another matter. It would be simple in most cases, were it not for the interference presented by the damaged soft tissues. The distraction force necessary to correct displacement in many cases is so great that transfixion pins bend or become displaced, or the soft tissues themselves tear, causing more extensive hemorrhage and swelling. The circulation in a badly swollen limb may become completely obliterated by long-axis traction in a distraction apparatus, particularly when tension is applied to a joint. The efficiency of skeletal traction when applied suddenly through a joint may be so reduced that it is often necessary to overextend the soft tissues in order to obtain reduction. Flexion of the fingers or toes, blanching or cyanosis of the skin, while traction is in force through the ankle or wrist joint, should warn one that the distraction force is too great. Traction under these conditions, if maintained, may result in a permanent palsy, due to ischemia. It should be remembered that muscle spasm, particularly when associated with hemorrhage or edema in the soft parts must be overcome by prolonged steady traction, rather than by a sudden powerful pull. Often shortening is due not only to muscle spasm, but to shortening of the musculature because of hemorrhage and edema in the muscle fibers themselves. This type of shortening cannot be overcome by a sudden traction or distraction force without severe damage to the muscle tissue. The immediate damage caused by overextension may lead to permanent fibrosis and contracture.

The rigid fixation provided by setting transfixion pins in plaster or in a splint after reduction has been obtained in a distraction apparatus, is of considerable advantage in maintaining reduction in certain types of fracture. Also it is hazardous. The greatest

caution must be exercised in obtaining proper reduction if this means of fixation is to be employed. The reduced fragments remain absolutely fixed in the position in which they are placed and muscle balance no longer aids in the reduction. The slightest amount of distraction between the fragments remains constant during the period of fixation and may lead to delayed union or to nonunion. Rigid fixation in spiral or oblique fractures, even when proper length has been obtained, often maintains enough separation caused by rotation to delay healing. (Fig. 16.)

In the treatment of fractures of both bones of the leg or forearm by fixation between two or more transfixion pins there is great danger of maintaining a small amount of distraction at the fracture site in one bone while the fragments of the other remain in contact. Union between the fragments in one bone will then maintain distraction in the other. This is a frequent cause of delayed union and nonunion. (Fig. 17.)

Although absolute fixation to prevent shortening or rotation can be maintained by fixation with one pin above and one below the fracture site, angulation in the anterior-posterior plane cannot be avoided unless more than two pins are used. This is a common fault of the two-pin fixation method of treating fractures of the shaft of the tibia. Excellent reduction may be accomplished and the leg placed in a long leg cast with the pins incorporated in the plaster, only to find that motion of the body leads to rocking of the upper fragment with the upper pin acting as a fulcrum. (Fig. 18.) The resulting angulation at the fracture site may lead to pressure necrosis of the skin over the tibia and to compounding of the fracture. (Fig. 18.) The use of multiple pins to prevent this rocking motion is dangerous and unwarranted.

During the past few years the ambulatory treatment of fractures has grown in favor. Many fractures, particularly those of the lower extremities, which ordinarily could not be treated in this category for fear of displacement, are now allowed early weight bearing on transfixion pins incorporated in walking casts. Notwithstanding the admitted advantages of early weight bearing this practice should be discouraged. Walking in a cast with a transfixion pin above and one below the fracture site does not allow weight bearing at the site of fracture, which is of advantage. (Fig. 19.) Again, ambulatory treatment under these conditions tends to maintain any existing distraction and to favor development of the rocking motion previously described. Weight bearing on transfixion pins is also liable to loosen the pins and encourage infection. Finally, patients under

treatment with skeletal traction must be under constant supervision and definite control which this type of ambulatory management will not allow.

SUMMARY

The misuse of skeletal traction rather than the application of the method itself leads to most of the difficulties associated with it.

The greatest danger of the method is infection, which may result from improper surgical technique at the time of application or from subsequent motion of the metal agent used for traction. A method of preventing longitudinal axis motion of skeletal pins is described.

The complications of infection are most severe when a hematoma, joint or linear fracture communicating with a major fracture are traversed by a traction pin.

Improperly placed pins may result in inefficient traction, pressure necrosis of soft tissues or severe damage to the bone or neighboring epiphyseal areas and joints.

The use of metal tongs is condemned, except for traction on the skull.

The problem of distraction resulting in delayed union and nonunion is discussed.

The hazards associated with the use of multiple points of skeletal fixation and distraction types of apparatus are emphasized.

The ambulatory management of patients treated by the incorporation of skeletal pins in plaster is considered dangerous, particularly when weight bearing on the skeletal pins is allowed.

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DISCUSSION

GUSTAV F. BERG (Pittsburgh): I think that skeletal traction by the use of the Kirschner wire, the Steinmann pin or the ice tong is going to lead us into an occasional difficulty. To any individual who intends to treat fractures, I should like to make a few recommendations.

Let us discuss a fracture of the femur. In Dr. Kellogg Speed's book on fractures, he describes the anatomic location of the fracture, laying particular stress on the muscles attached to the different regions of the femur. The fracture of the upper third always assumes a characteristic position, caused by the pull of the attached muscles. If a fracture is seen early and receives proper attention, it can be reduced, and if the proper type of fixation apparatus is applied, it can be held in its proper position.

In case you desire to use skeletal traction in a fracture of the femoral shaft, there is a scientific way to go about it. The *x*-ray findings should be studied, a diagram made of the fractured shaft of the femur, and the angles in which the wires are to be inserted should be considered, in order that when proper traction is applied, the traction is in such a direction that it will both correct and prevent any recurring deformity, and not alter the proper angle of the articular surfaces of the joints. It is important to remember that Kirschner wires have a tendency to bend, and any appliance used to control the Kirschner wire must have attachments to prevent this bending.

I feel that in many cases, the incorporation of the Kirschner wire or the Steinmann pin in a plaster cast is a mistake if the fixation material is a circular plaster cast which prevents early motion of the adjoining joints.

In looking back over past experiences, what have been the anatomic structures which were responsible for the disability following fractures? Is it not a fact that the contracted structures surrounding the joints, the myofascitis and the fibrositis are the result of long continued disuse and that such factors must be eliminated? In dealing with a long spiral fracture, what usually happens? A piece of bone pushes its way through the soft structures and it is at times impossible to free the soft structures by the use of skeletal traction. At the removal of the traction the fragments are still displaced and the interposing soft structures cause nonunion. I am of the opinion that following the anatomic approaches as laid down by Dr. Henry, a skillfully performed open reduction, using the nofinger touch technique, performed by a competent surgeon, will give the best end result.

R. ARNOLD GRISWOLD (Louisville): This is a most timely paper of Dr. Mathewson's. Those of us who are enthusiastic about the use of skeletal traction fully realize, I think, the dangers and the pitfalls of this method. Skeletal traction with its logical sequences of countertraction and skeletal fixation in plaster are operative surgical methods, and they have all the dangers of abuse and misuse that other operative surgical measures have. They must be carried out with due regard for their indications and

contraindications, and with meticulous attention to the details of the technique.

Obviously, such operative methods are not indicated in fractures which can be handled by external manipulative reduction and external fixation. One sees double Steinmann pins or double Kirschner wires used in cases which should have been treated by simply manipulative reduction and plaster cast. More radical methods should be reserved for those cases in which such reduction is impossible, as for example, the compound fractures in which we have extensive comminution which prevents locking of fragments and in which we desire some method of adequately treating and observing the wound without sacrificing position. Also, in those simple fractures in which position cannot be maintained except by open operative methods.

From the standpoint of infection, I think the likelihood of bone infection is less in the hands of the average man when skeletal fixation is used, inserting the pins at a distance from the hematoma, that it is if that same man did an open operative reduction and internal fixation. Adherence to the details of technique implies that we consider this a major surgical operation and insert the pins with all the ritual of such a procedure. It is not a thing to be done in bed or in a farm house or on a kitchen table.

The points which Dr. Mathewson has brought out cover almost all my ideas of the details of technique, the proper insertion of the pin in relation to the line of pull, and avoiding the insertion of the pin through the hematoma of the fracture. The hematoma is much more susceptible to infection than are the bone and soft tissue at some distance from the fracture. In inserting the pins, we drive them through the bone in order to increase the amount of fixation and prevent motion. It is extremely important to drive pins, however, only through the cancellous structures at the extremities of the bone. Driving a Steinmann pin through the hard cortical bone in the midshaft will split the bone. We should pay particular attention to the point at which our skeletal fixation transfixes the bone in order to avoid splitting.

With careful attention to these details and avoidance of distraction, this method is a valuable adjunct in the treatment of the more severe types of fractures.

Rocking of the bone on the pin I have not seen in cases in which non-padded plaster casts were used and in which the joint above and below the fracture was fixed in plaster. I can see that it could occur even in a long cast in the case of padded plaster of Paris. In order to get weight-bearing on the fracture site during ambulatory treatment, we should avoid distraction. Before we put the plaster cast on, traction is released enough to get firm, hard contact of the bone ends, not impaction but pressure. The upper pin, at least, should be removed at the earliest possible moment.

I think this is an extremely valuable paper, and I hope it will be widely read and accepted, because abuse of skeletal traction may bring it into disrepute.

JOHN A. CALDWELL (Cincinnati): I heard nothing to which a person experienced in the use of skeletal traction could take any serious objection. My purpose is rather to comment on some of the skeletal traction procedures, and particularly on the excessive use of the method. Personally, I have not been able to see any particular reason for the use of a Kirschner wire. The difference in diameter does not particularly reduce liability to infection. The Steinmann pin is simpler, it is cheaper, it is put through with less formality, and it is a safer thing to use; and it does not require an expensive and complicated contrivance to keep it taut.

I cannot see any reason for driving a pin through. As Dr. Griswold has said, if you do it in cortical bone, you are almost certain to split the bone, and when it is rotated through cancellous bone, it engages firmly enough so that the limb does not slide back and forth on the pin.

I agree particularly with the abolition of any sort of dressing over the point of emergence and insertion of the pin. The frequent changing of those dressings, the application of antiseptics around them, leads to skin irritation, and our experience has been very much better since we abandoned them entirely.

The application that we put on in the first place for the purpose of coagulating the serum and sealing the pin tight is a solution of gentian violet.

Recently the market has been flooded with various types of distraction apparatus. The great value of this is that a person can buy it and use it and it is not necessary for him to bring to bear any basic understanding of the principles of handling fractures; in fact it is hardly necessary, according to some of the circulars, for him to cerebrate at all when employing it; he simply has to read the literature. The result is that these things have often been used, as Dr. Griswold has mentioned, when there was no excuse for them at all. Reducible fractures have been put up with two pins, and what I think is just as bad, multiple pins have been used in cases in which a clean, well-conducted, open operation, followed by the encasement of the limb in a cast, would have put the patient back on duty very much sooner.

This sudden terror of open operation where it is really indicated is difficult to understand. In the hands of a surgeon accustomed to doing this variety of surgery with the right facilities available, the results are favorable.

The popularity of distraction apparatus, of course, is just the result of a human trait to which Benjamin Franklin called attention. The man who pays a pound for his whistle is very apt to blow on it whenever he has any excuse at all.

It is hardly possible, I think, to overemphasize some of the dangers of the indiscriminate use of skeletal traction. In the general run of cases it is comparatively innocuous, but you simply cannot stick pins in bones and keep on doing it indefinitely—sometime or other you will shudder at the mere sight of a pin. Nevertheless, considering the simplicity of skeletal traction, the comfort of it after it is installed, and its effectiveness, it is obvious that it has an established and very useful place in surgery. To be

entirely just when comparing its dangers with those of skin traction one must not forget the pressure sores, ineffectiveness, cellulitis, and constant discomfort present to some degree in every case of adhesive plaster traction.

LAURIE H. MCKIM (Montreal): I should like to ask Dr. Mathewson what he thinks of the use of the extension method by wire through the os calcis and whether he thinks the hazards in the os calcis greater than in other bones of the body.

DONALD GORDON (New York City): It seems to me that the situation as we have it at the present day is—There are certain fractures that we can take care of by simple manipulation and reduction; there are certain cases that have to be taken care of with skeletal traction; and there are certain cases where, if one has an adequate organization, it is imperative to go in, reduce the fracture and use an internal fixation.

Dr. Mathewson's paper is very timely. The facts that have been called to our attention about the high pressure salesmanship of gadgets are most important. The younger men, who have not had a long experience in the treatment of fractures before these gadgets appeared, consider that their problems are answered by these devices. We, who have come along the years, know that this is not the case.

In one of the first fractures I treated with skeletal tongs, a good many years ago, the tongs slipped and I was under the necessity of making the same sleeve protection for the tongs to prevent penetration of the point, that Dr. Mathewson has applied to the pin.

If one has instituted tong traction, which is embraced by "skeletal traction," there is a penetrating action from both sides, but there is also a great deal of graving action due to the pull forward. If this is a locked or fixed tong and is not watched, one tooth may penetrate one side and let the long tooth come out of the bone grip on the opposite side. With a sleeve on the tongs this is obviated just as Dr. Mathewson has said. It is excellent in principle and very desirable.

The truth is coming out regarding Steinmann pins. The Steinmann pin is essentially a drain to its bony position. On the other hand, as Dr. Robert Wagner of Pittsburgh mentioned in a paper he read in New York a few weeks ago, "It isn't the mechanical device one puts into a wound, it is the infection one carries in with it." A Steinmann pin can be introduced under good conditions, a small incision made, the skin separated, the pin put in and skin edges treated as one likes. If there is any chance of infection around the skin incision, I personally like to use grease to prevent crusting and retention of drainage. If any infection which has been carried in does not have adequate drainage, the pin is prevented from acting as a drain. When the times comes to take the pin out, it is properly prepared and cleansed. On its removal I take the little rubber tubing used to cover the ear wires of spectacles and follow the pin from one side with a piece of the tubing. As the pin is pulled out, I run the tubing through and then put in another piece on the opposite side. If there is any question in my mind

about infection having been carried in, or infection around the soft parts, Carrel technique is instituted. The tubes are so small that they have to be irrigated with a hypodermic needle. If that is a disadvantage due to the corrosive action of the solution on the steel needle, one can glue to the smaller tube with ambroid glue, a larger caliber tube which accepts a glass eye dropper. The wounds are dressed, as for a regular Carrel technique, with vaseline gauze. The wound is irrigated for several days with Dakin's solution until infection has been brought under control. Then the tubes are gradually withdrawn and, if there is any fear of remaining infection, the outside of the wound is treated with a 3 per cent salicylic ointment made from boric ointment without the wax, to prevent crusting. Up to the present, I have not had any difficulty from these wounds with either early or late infection.

Regarding distraction, Dr. Robert H. Kennedy of the Beekman Street Hospital, New York City, stated that when they get a distraction with Russell traction, they get delayed union. Distraction means that the muscles have lost their tone. As I see it, there is only one way for such muscles to regain their tone, and that is by the patient's activating them. The muscles of a limb can be activated if that limb is enclosed in a solid cast. There may be no visible movement of the joint, but the patient is taught to activate his muscles. It is helpful to his muscle sense to have him activate the same muscles of the other leg. There will be a certain degree of preservation of muscle tone in those muscles whether they are in a cast or in a Russell traction, tending to prevent and even overcome slight distraction.

A. William Reggio (Boston): There is one more thing that might also be included in the misuse of skeletal traction, and that is a mistake seen frequently, made by men treating subtrochanteric fractures of the femur. They pull the daylight into (as well as out of!) the fracture, forgetting that in this type of fracture you have to bring the distal portion of the fracture to the proximal, because of the rotation, abduction and flexion of the proximal fragment. This simply means that they do not recognize the muscle pulls in the fracture. We see only too often that they expect to obtain reduction with the leg kept straight in bed instead of in rather wide abduction and flexion. The position of the limb is of great importance in the efficiency of skeletal traction.

Carleton Mathewson, Jr. (closing): I should like to thank the gentlemen for their comments.

Dr. Griswold says that he has never seen the rocking motion in the upper third of the tibia. I feel very happy for him, because we have used both padded and non-padded plaster casts and have found that the non-padded plaster will not prevent this motion. I have been able to demonstrate this motion to students by simply cutting a small window over the fracture site and requesting the patient to rock up and down in bed. With motion of the body, anterior-posterior motion takes place at the site of fracture.

I agree with Dr. Griswold that when we do use two pins for traction and countertraction it is wise to remove the upper pin as soon as possible. The "proper time" is that time when the fracture site becomes sticky. We then take out the upper pin and occasionally allow weight bearing on the limb.

Dr. Caldwell spoke of the Steinmann pin versus the Kirschner wire. I think that this is like talking about catgut versus black silk and prefer not to discuss the question further except to say I like a small caliber pin because the initial damage to the bone is less.

Dr. McKim asked if I thought the hazards were greater in the os calcis than elsewhere. I can only say that if you recognize the hazards associated with skeletal traction and prevent them, you are justified in using it whenever indicated. I believe that we have not seen any more trouble with pins in the os calcis than elsewhere when we have been careful to adhere to the principles associated with the use of skeletal traction. We must prevent motion of the pin and unless we do we will get into trouble. It makes little difference how small or how large the pin, motion eventually will cause infection.

Dr. Gordon spoke of tongs. I have written of them in my paper. They are mentioned only to be condemned because even in the hands of experts tongs are exceedingly dangerous. We use the same method described by Dr. Gordon when using tongs on the skull to prevent penetration deeper than the outer table.

I quite agree with Dr. Gordon regarding the necessity of proper physiotherapy for the muscles. In all cases in which it is possible to get the patient to early weight bearing in non-padded plaster casts, we can preserve the motion of their joints even though they are unable to move in the plaster.

Dr. Reggio spoke of subtrochanteric fractures. I might add that you must not forget that the relaxed hip goes into complete external rotation. Unless you externally rotate as well as abduct the distal fragment, you will not get proper reduction.

TREATMENT OF INTERTROCHANTERIC FRACTURES OF THE FEMUR BY MODIFICATION OF RUSSELL BALANCED TRACTION*

VINTON E. SILER, M.D. AND JOHN A. CALDWELL, M.D.

CINCINNATI, OHIO

THE ideal contrivance for fixation of a fracture should meet the following requirements:

1. It should hold the fragments in apposition and not give discomfort.

2. It should (as a rule) immobilize the joint above and below the fracture.

3. It should relieve discomfort.

4. It should permit inspection of fingers or toes in order to determine if circulation has been impaired.

The above requirements are as old as fracture surgery itself and meet with practically uniform acceptance in principle if not in expression.

Beginning with Hodgen's suspension splint, then the adoption of the Metz or Balkan frame, the advantage of suspension in counterbalance has gradually been accepted, until now a fifth requirement may be added as a sine qua non for comfortable management of a broken bone.

5. The apparatus must move with the patient. When this condition is met, the patient can shift his position in bed to have his bed linen changed—to be put on a bedpan, to be bathed, without having the relative position of fragments changed.

In 1924 Russell of Melbourne described what was soon recognized as an extremely simple and uncomplicated form of balanced traction. Having the same weight supply both traction and counterbalance removed one troublesome feature which often mystified house officers and nurses.

The intertrochanteric fracture is one of the problems in bone surgery. Similar in age, incidence, and causative trauma with the intracapsular fracture, it is associated with the same nursing problems, such as obesity, incontinence, tendency to decubitus, and

* From the Fracture Service, Department of Surgery, Cincinnati General Hospital.

mental states which make for noncoöperation. In many cases systemic states prevent an abduction cast, and comminution of the great trochanter may make it unfeasible to employ pins, screws

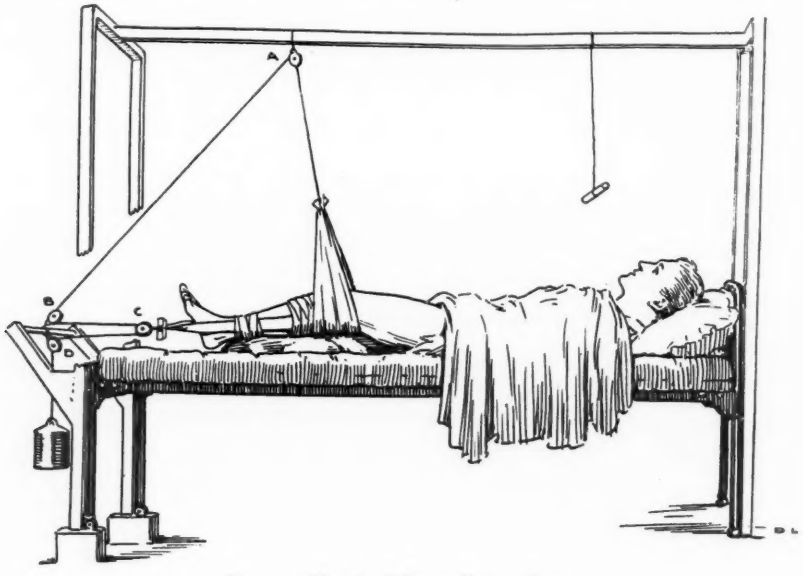

FIG. 1. Classical Russell traction.

or any direct fixation. Many of the patients have but a short time to live, but during this period of survival they must be nursed, kept clean, and cared for without torture.

It is in this group that we found the Russell traction a great boon. The patient can sit up almost straight in the Fowler position, can have his back cared for, his bed linen changed, and use a urinal or bedpan, without causing displacement of fragments.

We had used Russell traction but a short time when we recognized the many advantages it had to offer, but we also discovered two undesirable features: (1) Prolonged use of traction by means of adhesive plaster cannot be maintained in many elderly patients because of dermatitis. (2) Russell's form of balanced traction suspends the leg in a sling about the knee. Such suspension causes some pressure on the popliteal artery which, combined with elevation of the limb, imperils a circulation already impeded by sclerosed arteries. A third objection noted was that rotation of the leg could not be controlled when Russell's traction was employed.

To meet the objections enumerated above, we devised a modification of Russell's traction, which did not sacrifice any of the principle employed nor complicate its use. Practically the sole change was in substituting skeletal traction for adhesive plaster.

For a number of years we have used the Steinmann pin almost exclusively for skeletal traction. It is much cheaper and simpler, and just as safe as Kirschner wire—and is also cheaper and much

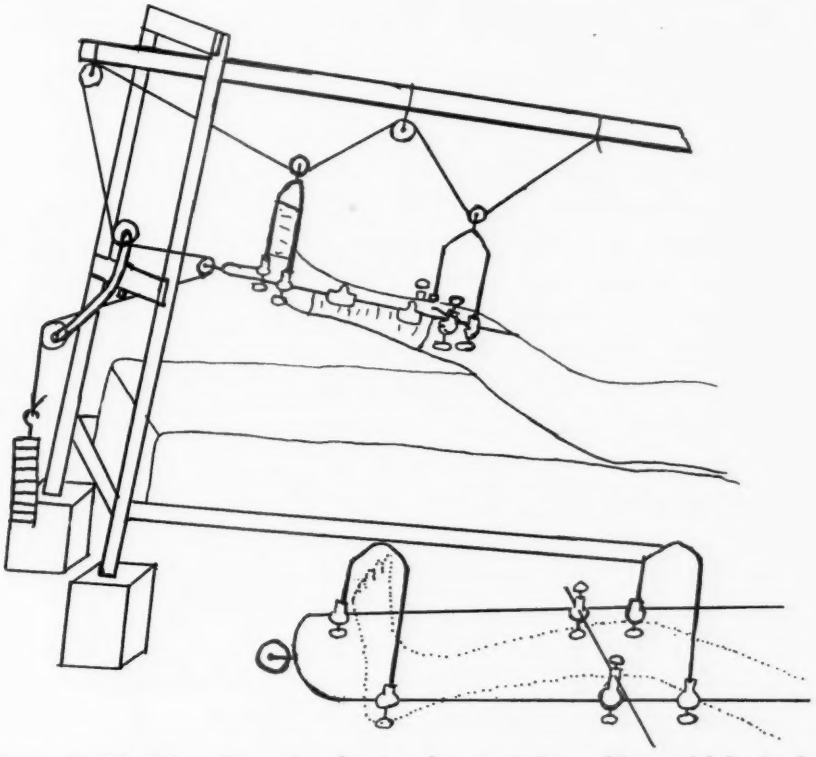

FIG. 2. Modified Russell traction showing the use of pins and lugs, with leg in the metal loop.

more safe and certain than ice tongs. Our pins are made from 5/32 stainless steel which we buy in lengths, and have cut and sharpened in our own shop. When we use pins with a Thomas splint, we customarily clamp a special lug to either end of the pin by means of a set screw, which in turn is fastened to the bar of the Thomas splint with another set screw. Traction is then made on the end of the splint. The lugs are also useful to fix segmental fractures by means of multiple pins clamped to the side bars of a Thomas splint.

In order to use skeletal traction with the Russell principle a piece of 5/16 inch steel is bent into U shape slightly wider than the leg, and 6 inches longer. A pulley is attached to the bottom of the U. A Steinmann pin is passed through the tibia at the tubercle and each end fastened to the side bars of the U.

Most of our Steinmann pins are inserted under local anesthesia—and the fracture is also frequently rendered painless by injecting

2 per cent procaine into the hematoma about the break. In the use of local anesthesia in fracture work we insist that no manipulation or puncture which might cause pain shall be begun until at least ten minutes have elapsed since the injection. The pin is always inserted by rotating—never driven. It is usually chucked in the ordinary mechanic's breast drill.

While our asepsis is rigid, no great formality is observed. Skin is sterilized over a small area—the operator does not scrub—and the pin is the only instrument boiled. Draping is with towels only, and the insertion of the pin is often carried out in the patient's bed. When the pin has been fixed in position, no dressing is applied where it enters or emerges from the skin, but a small area of the skin about the pin is painted with gentian violet. For some time we carefully covered the pin and the skin near it with alcohol dressings which were changed daily, but this regimen was followed by rather a high proportion of dermatitis and occasional skin infections. We then changed to an application of 2 per cent tannic alcohol with no dressing, and this was followed with but very few instances of infection. Since we have been using gentian violet, skin infection has almost disappeared. We feel that movement of the bone on the pin is a great factor in predisposing to infection.

In the 103 cases of modified Russel traction in which a pin was used, there was mild infection in twenty-one cases, and in three cases more severe infection with some degree of osteomyelitis. In all of these infection promptly subsided after removal of the pin, so that in none was there any permanent serious sequel.

When it is considered that a pin was used for an average period of fifty-one days in those patients who survived, and for twenty-one days in those who failed to survive the treatment, the employment of a Steinmann pin as a means of skeletal traction cannot be considered a hazardous procedure. In considering the hazard of skeletal traction, if one is to be just, it must be remembered that traction by adhesive plaster is almost constantly associated with minor discomfort, often sufficient to cause its abandonment, while occasional serious sequela are seen—examples are two cases of gangrene of the leg, two of cellulitis, and three of food drop from peroneal nerve pressure.

A statistical analysis follows of 103 cases treated during the five year period of the years 1933–1937 inclusive. Those cases treated in 1938 were too recently seen to justify a fair appraisal of their outcome. The cases were all from the Cincinnati General Hospital, a tax-supported charitable institution. In many of the patients who

are brought to such an institution the factors which make for poor surgical risks are present to an abnormal degree: senility, indigence, undernourishment, alcoholism, and mental impairment. Bearing these facts in mind there is abundant explanation for the mortality rate of 30.23 per cent.

AGE

	No. of Cases	Average Age
Total	103	70.41
Males	44	67.64
Females	59	72.49

RACE AND SEX

	Female		Male	
	No.	Per Cent	No.	Per Cent
White	54	52.42	5	4.85
Colored	40	37.86	4	3.88

SIDE OF FRACTURE

	No.	Per Cent
Right	58	56.3
Left	45	43.7

As regards the time factor from initial injury to the application of modified Russell's traction, there was a variation of from one hour to twenty-eight days.

Infection about the modified Steinmann pin inserted in the upper third of the tibia was present to a slight degree in twenty-one cases, and to a marked degree in three cases, giving a total of twenty-four, or 10.33 per cent. In the three cases showing severe infection there was definite osteomyelitis at the site of the pin, one of the three being very extensive and the others being of a slighter extent. All three healed.

The average duration of modified Russell's traction in seventy-two recovered cases was 51.19 days. The average duration of modified Russell's traction in the thirty-one patients who died was 21.34 days.

The average length of time in bed after the removal of traction in the recovered cases was 24.71 days. The average length of time in

bed after removal of traction in seven of the cases which died was 22.45 days.

The average total hospital days in the seventy-two cases which

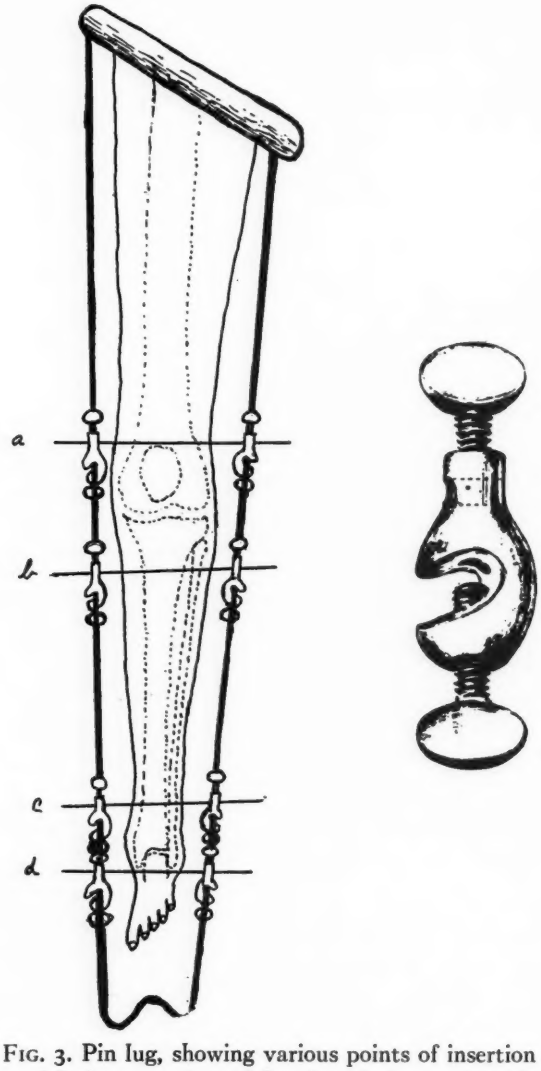

FIG. 3. Pin lug, showing various points of insertion of Steinmann pin and fixation of pins to the side of Thomas splint with lugs.

recovered was 87.89 days. The average total hospital days in the thirty-one cases which died was 28.16 days.

Other forms of treatment instituted after discontinuing modified Russell's traction were: (1) position of comfort—knees flexed; (2) anti-eversion boots; (3) body spicas; (4) physiotherapy.

The general mortality rate of the entire series was as follows:

Number of cases	103
Number of deaths	31
Mortality rate	30.1 per cent

Year	No. of Cases	Deaths	Per Cent Mortality
1933	18	4	22.22
1934	22	5	22.73
1935	28	8	28.57
1936	19	10	52.63
1937	16	4	25
Average	..	..	30.23

The causes of death in the thirty-one cases were as follows:

	Number of Cases	Percentage of Total Deaths	Percentage of Total Cases
Bronchopneumonia	24	77.45	23.28
Coronary occlusion	3	9.67	2.91
Pyelonephritis	1	3.22	0.97
Head injury	1	3.22	0.97
Pulmonary embolus	1	3.22	0.97
Unknown	1	3.22	0.97

The results in seventy-two cases, according to *x*-ray evidence of anatomic position were as follows:

	No. of Cases	Per Cent
Good	52	72.2
Fair	13	18.1
Poor	7	9.7

"Good" signifies *x*-ray evidence of satisfactory reduction with no overriding or displacement. "Fair" signifies slight overriding or malposition. "Poor" signifies displacement or overriding.

RESULT IN SEVENTY-TWO CASES ACCORDING TO FUNCTION

	No. of Cases	Per Cent
Good	59	82.0
Fair	6	8.3
Poor	2	2.8
Unknown	5	6.4

"Good" signifies slight or no shortening with no impairment of function. "Fair" signifies moderate shortening with slight impairment of function. "Poor" signifies considerable shortening with definite impairment of function. "Unknown" signifies no follow-up.

RESULT IN SEVENTY-TWO CASES ACCORDING TO X-RAY AND CLINICAL EVIDENCE OF UNION (CALLUS)

	No. of Cases	Per Cent
Good	57	79.2
Fair	12	16.6
Poor	3	4.2

"Good" signifies normal response of callus. "Fair" signifies delayed union. "Poor" signifies non-union.

In the seventy-two patients who recovered there was no correlation between the presence of syphilis and callus formation.

	Negative Wassermann	Positive Wassermann	No Report on Wassermann	Total
Union (good)	44	4	9	57
Delayed union (fair)	8	3	1	12
Nonunion (poor)	3	..	..	3

CONCLUSIONS

1. Certain intertrochanteric fractures, notably those which cannot be pinned or encased, can be most comfortably treated in some form of balanced traction.

2. The Russell traction is simple and effective, but unsuitable, because (1) rotation cannot be controlled; (2) the pressure of the sling on popliteal vessels with the leg elevated imperils circulation; and (3) prolonged traction with adhesive plaster is not well borne.

3. Traction by means of the Russell method modified as described is comfortable and meets the objections enumerated.

4. Skeletal traction is most simply and effectively made by means of a Steinmann pin. The pin fastened to the supporting frame by means of the lugs described makes a simple and comfortable arrangement for support and traction.

DISCUSSION

HENRY C. MARBLE (Boston): I think this is a very interesting paper. In 1915 or thereabouts, I visited Dr. Chutro in Paris. To obtain traction on the leg, he inserted a flat wire over the os calcis. This was called a Finochetti stirrup. The knee was flexed and the hip was flexed. There was no suspension or Thomas splint. The lower leg rested upon two pillows.

Shortly after, the Steinmann pin came into being. We drove this pin through the os calcis.

One day in about 1922, a kindly gentleman visited our clinic at the Massachusetts General Hospital. During his visit he drew on the back of an *x*-ray folder a small diagram of a new method of traction. It was a parallelogram in which the various lines of force were carefully worked out. When it was all over, I quietly inquired his name, and he said he was Dr. Russell. We tried his traction rather diligently without a great deal of success, and discontinued it. We then went back to the Thomas splint. About that time we had a patient admitted to the ward who was very feeble, had diabetes, and required large doses of insulin. She had fallen and had an intertrochanteric fracture of the femur. Despite our diligence, she died at the end of the fifth week. At autopsy it was found that she really died of inanition.

We took out the specimen of the hip. It so happened that just about that time there was a clinic in Dr. Harvey Cushing's hospital and Dr. Star of Toronto visited us. We all took the specimen in our hands and tried to bend it. It was impossible to get any motion at all at the site of fracture.

All of this led me to believe that intertrochanteric fractures of the femur heal rapidly, thoroughly, and completely, and are sufficiently united in four or five weeks. Traction is the essential in the treatment of the intertrochanteric fractures. Russell used suspension and got good results. Chutro did the same with the Finochetti stirrup. Steinmann accomplished the same thing with his pin.

Dr. Caldwell has now united the Steinmann pin and the Hodgen's splint to get the same results. That is all that is necessary. This is an excellent and very commendable addition.

I want to say one more word on the matter of internal fixation. In view of all this, why anyone should want to subject these poor, unfortunate people to pins, nails, spikes and screws when the fracture is going to heal in four to five weeks with a little well applied traction, I cannot understand. I do not think that internal fixation is indicated or necessary. Don't misunderstand me—in an intracapsular fracture, I am strongly in favor of internal fixation. In a subtrochanteric fracture there is a different problem. But this particular problem—the intertrochanteric fracture—can be treated by simple, effective traction, and I do not think internal fixation is called for.

PRESTON A. WADE (New York): Dr. Caldwell has given us something of great value. He has limited his method to cases which are not suitable for internal fixation or other methods of treatment. I know he uses internal fixation in some intertrochanteric fractures.

In the last few years, at the New York Hospital and on one service at City Hospital, we have been using internal fixation in certain cases of intertrochanteric fractures in which there was no comminution of the greater trochanter where we feel that the nails will not cause splintering of the bone and loss of position. We have used the multiple pins, the Moore nails. We have never used the Smith-Peterson nail in these cases because of the danger of splintering the upper end of the lower fragment. We have been

careful to choose those cases in which we feel that the internal fixation will be satisfactory.

So far we feel that this method of treatment is of value, chiefly because the patients are kept in bed only a few days, are allowed up on crutches early, and do not have joint disabilities in knee and ankle.

I know there is a difference of opinion about whether these cases should be treated by so-called radical treatment. We feel that internal fixation in some of these cases is really conservative treatment, more conservative than fixation in a plaster or traction.

We have had one unfortunate experience after nailing one of these fractures in an older person. The patient was not able to use crutches very well. She slipped and fell and fractured her femur below the point of internal fixation, because the long, oblique fragment could not stand the strain of the added weight.

In cases unsuitable for nailing, we have employed Russell traction, and have used it with considerable success. We must admit its disadvantages, as Dr. Caldwell has outlined. In some patients, particularly older people whose skin cannot stand long continued traction by adhesive, infections result from skin irritation. In one case a rather severe cellulitis developed in the leg and was followed by a suppurative arthritis in the ankle, necessitating amputation.

We have had three cases of foot drop from improper application of the adhesive in Russell traction. Since we have had these complications, we have been very careful to protect the peroneal nerve.

We have encountered some irritation of the skin in the popliteal space, but have not seen any severe damage to the circulation.

Russell's original article in 1934, in which he described his method, referred to frequent criticisms in regard to eversion. He stated that the sling under the knee prevented eversion and that he had had no trouble at that time with external rotation. However, it is true that one does have difficulty with external rotation of the lower fragment, and Dr. Caldwell has given us a method which overcomes this objection.

W. L. Estes, Jr. (Bethlehem, Pennsylvania): I have been very much interested in Dr. Caldwell's paper because we have been using a modification of the Russell traction apparatus largely because of the difficulty in controlling the upper fragment in fracture of the femur by the usual *simple* Russell traction. Feeling that it is desirable in many instances of fracture of the middle and upper thirds of the shaft of the femur, we have used the Russell traction in connection with the Pierson attachment of the old Thomas splint. In that way the position of the entire lower extremity can be properly controlled in any desirable abduction or external rotation. The lower fragment can be brought in alignment with the upper, and still maintain the Russell principle type of traction. This we have found efficacious in a few intertrochanteric fractures, in fractures of the middle and upper thirds of the shaft of the femur, but we have not found Russell

traction satisfactory in fractures of the lower third of the femur, and have felt that some other method of traction should be used in this location.

KENNETH M. LEWIS (New York City): I have been much interested in both Dr. Caldwell's method and the method Dr. Estes brought out. On the other hand, one of the fundamental principles of Russell traction is putting the muscles at physiologic rest. One reason for getting away from elevating the leg in a Thomas splint with a Pierson extension and flexing the thigh too much was the fact that this throws certain thigh muscles into spasm and defeats a good deal of the traction. The question of physiologic rest of the muscles, slight flexion at the hip and slight flexion at the knee, is just as important as the mathematical calculations that go into the construction of the parallelogram of traction arrangement.

We have had ninety-eight intertrochanteric fractures on the fourth surgical division at Bellevue Hospital during the past five years. We have used Russell traction routinely and have sensed excellent results. We feel that it is extremely important in any of these methods to apply traction early—as soon as the patients are admitted, even if this is 3 or 4 o'clock in the morning. We have been able to reduce them all, and as Dr. Marble says, unions are practically 100 per cent. We have had one nonunion in the series of ninety-eight cases.

I would like to mention that we have also had the same difficulty in rotation of the fragments in fractures of the tibia. We have entirely given up the two-pin method of treating tibias whether it is the Anderson apparatus or one of the allied methods.

JOHN A. CALDWELL (closing): Regarding the lines of force with the suspension in two places with the pulley—with the leg level and the thigh slightly flexed, if the principle of parallelogram of forces is applied, it will be found that the line of traction is in the long axis of the femur. I do not think there is any change in the direction of pull in this modification over that in the original one described by Russell.

We have not employed this method for treatment of fracture of the femur, preferring the Thomas splint with the Pierson attachment, an arrangement similar to the one which Dr. Estes has mentioned, except that we also use a pin through the tubercle of the tibia to make the traction. That gives a little more support to the shaft and somewhat greater flexion of the knee and of the thigh. The suspending force is not the same one which makes the traction.

Really, this paper should hardly be called a method of treatment of intertrochanteric fractures. I think a better title would be "a method of nursing patients with an intertrochanteric fracture." The whole purpose of this is to counterbalance the patient and put him in such a comfortable position that he can be changed and taken care of without being harassed.

What Dr. Marble said about union, of course, is quite true; these fractures practically all unite, but the trouble is during the period before they have united, unless they are put up in some way that allows com-

fortable nursing, the patients are tortured quite a bit. For that reason and that reason alone, we prefer internal fixation when there is no contraindication. The patient who can have his femur nailed can be gotten out of bed in a week or ten days. That is much better than any method that keeps him bedridden for from six to twelve weeks.

The method of Dr. Estes is similar in principle to the Russell traction, except that it is a little more complicated. The suspending force is not the pulling one.

A SIMPLE EFFECTIVE METHOD FOR THE TREATMENT OF FRACTURES OF THE UPPER TWO-THIRDS OF THE HUMERUS

FRASER B. GURD, M.D., F.R.C.S. (CAN.)

MONTREAL, QUEBEC

IT is not my intention in this contribution to claim any originality in the treatment of fractures involving the upper two-thirds of the humerus. As the title indicates, I wish simply to describe a method which has proved satisfactory in our hands over a period of about twenty years. No attempt is made to present a statistical study of end results; I wish, however, to make the statement that in no case during the past twenty years have we had cause to regret the employment of the method. There has been no case in which important loss of function of either shoulder or elbow joint has occurred, and non-union has been encountered in not one case treated by this method in our clinic.

Although the title should include fractures of the anatomic neck and of the great tuberosity of the humerus, the method described has not been used in the treatment of these cases. Since fractures of the anatomic neck occur almost exclusively in elderly people, and since each individual case must, I believe, be considered to be a special problem and the treatment thereof individualized, no routine method of treatment of this fracture can, I believe, be recommended.

Fractures of the surgical neck are common injuries. Fortunately, as a rule, comparatively little deformity is present. Also, it will be agreed, I believe, that in those cases in which any considerable deformity is present it is marked. In such cases of extreme deformity associated as it is with displacement upward and inward of the upper end of the lower fragment, I believe open reduction should be undertaken after but a short attempt at reduction by traction, sometimes assisted by manipulation under an anesthetic.

It will be noted that I do not purpose taking up the matter of fractures through the lower third of the humerus. Such fractures are in my opinion frequently difficult to handle and cannot be treated in a routine manner. The method described in this con-

* From the Montreal General Hospital, McGill University.

tribution may frequently be properly used as a convalescent apparatus but is not adapted to the early treatment of such cases.

In all other cases of fracture of the surgical neck and fracture

FIG. 1. Anterior view of patient with axillary pad fitted. Note amount of abduction, method of fixation and projection forward.

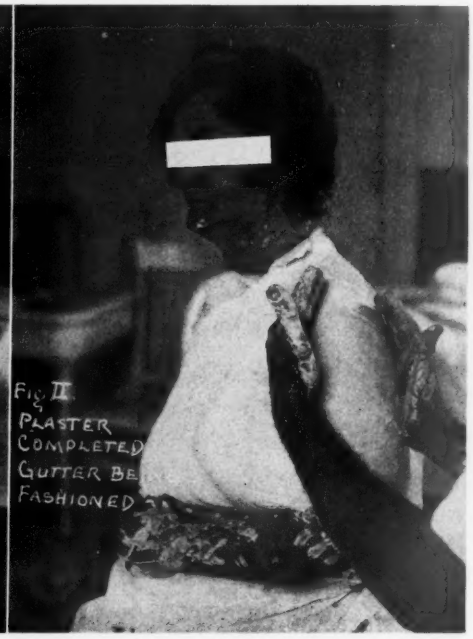

FIG. 2. Application of plaster completed. Gutters are being fashioned. Note position of pad covered with plaster.

of the middle third, whether oblique or transverse, the method which is described has been employed routinely. Fractures in the middle third of the humerus are either transverse or spiral. Fortunately, interposition of tissue is unusual, but obviously when it is encountered operative interference for removal of the tissue lying between the fractured ends must be undertaken.

A triangular shaped, firm pad is made of sheet wadding tightly compressed by means of a roller gauze bandage. This pad is sufficiently deep from top to bottom to press against the lower borders of the anterior and posterior folds of the axilla and to reach to the level of the forearm when the latter is flexed across the patient's body. It is sufficiently wide at its base to result in abduction of the arm at the shoulder to about 15 degrees—this amount of abduction is, I believe, sufficient to relieve the pull of the supraspinatus muscle and to permit contraction of the deltoid. From before backward the pad is sufficiently long so that, when lying flush with the back and the posterior border of the arm, it will reach sufficiently far

forward to project over the flexed forearm. The pad is fixed into the axilla by means of adhesive strips attached to the apex of the wedge and carried over the tip of the shoulder. (Fig. 1.)

FIG. 3. Anterior view, indicates direction of pull.

FIG. 4. Lateral view, indicates position of fulcrum and traction downward of arm. Position of incorporated coaptation splint is indicated by broken lines.

Three of four layers of sheet wadding are carried about the body under the opposite axilla outside the injured arm and over the shoulder on the injured side and so down under the pad so that the latter is kept firmly pressed into the axilla during the application of the plaster.

The upper part of the torso, the shoulder on the affected side, and the arm are encircled by 6 inch plaster bandages. A certain number of turns are carried from the tip of the shoulder down under the pad so that the under surface of the latter is covered with plaster. A coaptation splint made of one 4 or 6 inch plaster is applied from the root of the neck over the tip of the shoulder and down to the lateral condyle. This is incorporated in the circular bandage which, as indicated above, is applied outside the injured arm and around the body. Such a dressing is not heavy, and approximately five or six 6 inch bandages suffice for the purpose.

Just before the plaster sets it is moulded to the anterior and posterior surfaces of the arm with the heel of the hand in such a

way that two gutters are produced which prevent movement forward or backward when the patient bends or lies down. (Fig. 2.)

A wrist sling is applied so that, the elbow being free and the

FIG. 5. Felt pad in position. This increases traction power and protects forearm.

arm unsupported, a certain amount of traction is exerted downward by the weight of the arm distal to the point of fracture and the greater part of the forearm. Traction is then increased to any desired extent by straining the upper border of the forearm against the slightly convex lower border of the axillary pad. (Figs. 3 and 4.) If such straining is carried out before the plaster has entirely set, a shallow groove is produced into which the forearm fits. After the plaster is dry a thin felt pad is placed between the moulded plaster of Paris on the lower border of the axillary pad and so protects the forearm. (Fig. 5.) By pulling upward on the wrist by means of the sling any desired amount of traction may be obtained. It should be pointed out in this connection, however, that there is more danger of using excessive traction in this way than of using too little.

Since on the one hand it is not usually possible, particularly in stout persons, to apply plaster to the body when the patient is under an anesthetic, and since it is but infrequently necessary to employ an anesthetic to bring about reduction by this method of traction, it has been my habit to prepare the patient by means of a

mild sedative and, should more difficulty than usual be anticipated in bringing about reduction, to employ local anesthesia by the hematoma infiltration method.

The patient is advised that for the first couple of nights he will probably be more comfortable if he does not attempt to sleep lying down but rather stays in a large comfortable chair or propped up in bed; he is informed that it is inadvisable to place a pillow under the affected arm. Sedatives, as indicated, are prescribed. I have made it a practice to inform the patient or his guardian when first seen that, after a few days, considerable swelling, with probably discoloration and soreness about the elbow, is likely to be exhibited and should be expected. If this is not done the patient is likely to be alarmed when these phenomena, which are due to the seepage of blood from the site of fracture downward, has taken place.

Approximately seven to ten days after injury it is advisable to permit the patient to take the forearm out of the sling and, supporting the hand on the injured side by means of the uninjured member, commence active movement of the elbow joint. It is recommended to the patient that eight flexion movements be carried out in this way three times a day and that care be exercised that pain is not produced. From the very moment of injury it is wise, I believe, to urge the patient to exercise his fingers and wrist and to carry out the rotary movements of the forearm. Such advice avoids stiffness of these joints and results in a more adequate blood supply to the limb as a whole.

Second only to the quadriceps extensor of the thigh the deltoid muscle atrophies more quickly, I believe, than the other muscles of the body when put on the stretch and unused. Delay in return of function of the shoulder joint is most surely avoided by prevention in so far as possible of deltoid atrophy. In order that such atrophy may be minimized exercises are commenced about ten days from the date of injury. Although actual movement of the shoulder joint is prohibited by the retaining apparatus, both the supraspinatus and the deltoid can be induced to contract against the fixed resistance of the plaster, so that the strength and mass of the muscles are maintained.

Fractures of the surgical neck of the humerus heal comparatively quickly; depending upon the age of the patient the fixation apparatus may be removed in from two to five weeks from the date of injury. Following removal of the plaster the patient is supplied with a cravat sling with instructions to employ the limb actively so far as it is possible without pain and, at the same time, to continue

purposeful exercises of the muscles of both the arm and the shoulder girdle. As a rule, two to four months are required for substantially complete return of function to be obtained although at the end of six weeks from the date of injury it is usual to have reasonably good function of the arm exhibited.

Since it would seem that the same force is responsible for fracture of the surgical neck and of injury to the supraspinatus tendon, that is to say, to the floor of the bursa, it is not surprising that in some cases a prolonged period of disability due to the bursal injury is noted. When musculospiral (radial) nerve injury complicates the fracture, the lower half of the forearm and hand are fixed in the cock-up position and the apparatus otherwise applied as indicated.

Fractures through the middle third of the humerus require a longer period for union to occur than those through the surgical neck. It is possible with the apparatus in position to obtain adequate *x*-rays, to follow the course of calcium deposition and, also, to note clinical union without removal of the plaster. In the case of fractures through the middle of the bone, particularly of the transverse type, I have been accustomed to leave the apparatus undisturbed for a period of about eight weeks at which time it is removed and a careful check up of the situation carried out. Since in our experience the majority of musculospiral (radial) nerve lesions recover without operative interference, it has been our custom to postpone exploration of the nerve until union of the bone has occurred.

Although it is true that the typical deformity of the upper fragment in fractures of the surgical neck is one of more or less abduction and external rotation, it seems evident that, presumably due to the correcting force of the long head of the biceps when this powerful structure is made tense, moderate traction with the arm in internal rotation downward can be counted upon to bring about almost perfect reduction of fragments except in those cases in which an interposition of soft tissues has occurred. This fact has already been, I believe, clearly demonstrated by Griswold and others.

Since 1918 a number of authors have recommended from time to time the employment of the abducted position in the treatment of fractures of the surgical neck or middle and upper third of the shaft. Some have recommended the position of internal rotation, that is the so-called "airplane" position; others in external rotation, that is the so-called "traffic cop" position. For purposes of abduction, splints or plaster-of-Paris have been used as an ambulant method and traction abduction in a Thomas or similar splint, using either skin or skeletal traction, have been employed. Despite the

fact that these recommendations have been made, and despite the fact that certain of the junior members of my staff have employed such methods with, it is true in the main, satisfactory results, I have never been convinced that abduction resulted in either better anatomic position, shorter period of active treatment, or earlier or better return of function. Since, on the other hand, the abduction method is inconvenient if the patient is ambulant, and expensive if hospitalization in bed is employed, its only justification would be proof of better immediate and ultimate results.

With the exceptions noted in the introductory paragraphs the method which has been described fulfills, I believe, the qualifying adjectives employed in the title. It is simple in that it is easy to apply and it is inexpensive. It is effective in that it is comfortable for the patient and, by means of its employment, our results have been uniformly satisfactory. Since the patient is ambulant he may carry on his affairs if such activities do not require the use of both upper extremities. In any event, since hospitalization is not required for more than a few days at most, it is economical from the patient's point of view and, also, from the point of view of hospital beds.

DISCUSSION

GROVER C. PENBERTHY (Detroit): Dr. Gurd has called our attention to the need of individual treatment for each type of fracture. He has emphasized the advantages of the plaster dressing as he has described it for fractures of the upper two-thirds of the humerus.

I have had no experience with this type of fixation or reduction, but Dr. Gurd, in his twenty years of experience in using this type of traction and reduction and fixation, has had most satisfactory end results.

The disadvantages of the airplane splint or the arm abducted with plaster fixation has been emphasized. These are well known to all of us. This method of treatment allows the patient to be ambulatory and is economical as well as effective.

The economic aspect of fractures affects us quite materially in Detroit, especially at the City Receiving Hospital. We have had on the surgical service at the Receiving Hospital some forty patients treated by the hanging plaster dressing. In addition to the surgical service, the orthopedic service also treats these fractures with the hanging plaster and within the last two years Dr. LaFerté has reported a large series of cases in which the hanging cast was used.

At the Receiving Hospital approximately forty cases have been treated by this method. In no case was there nonunion, and in only one case was there delayed union.

I can, however, see a very material advantage to this dressing described by Dr. Gurd; the moulding of the plaster on the lateral aspect of the arm

fixes the humerus and it should therefore make a more comfortable dressing than the hanging plaster. Both methods are effective, and in both the patient is ambulatory.

We are indebted to Dr. Gurd for bringing this particular type of treatment to our attention.

D. C. PATTERSON (Bridgeport, Connecticut): I want to congratulate Dr. Gurd on the simplicity of his treatment in these cases. The less complicated the restraining apparatus the more generally satisfactory will be the results. Some of the splints and apparatus advocated for fracture treatment today are pretty complicated. An editorial in the British Medical Journal, referring to Hugh Owen Thomas, pointed out, "The appliances he invented and finally perfected have not yet been improved upon—modern so-called improvements have been retrograde."

I should like to demonstrate the use of the angle plate, advocated by Dr. George Hawley in cases of fractured humerus. [Films were shown.] The first part of the picture shows the results obtained in operations on dogs, carried out at Yale Medical School under the direction of Dr. Bassum. After the plate was inserted only a simple dressing was applied and the dogs were allowed up and about without any restraining dressings. In from two to five days they were running about with the operated leg apparently as firm as before the fracture. It is also apparent from the pictures that these dogs were suffering no pain.

The case of fractured humerus was in a young man of 31, one of our hurricane victims. He had a slightly comminuted, transverse fracture in the middle of the shaft of the right humerus. *X*-ray showed the distal fragment displaced completely anteriorly and slightly inward, with overriding of about 1 cm. Attempts to keep the fragments in good position with different splints and plaster were unsuccessful, and seven days after the injury an open reduction with application of the angle plate was performed. After exposure, the bone ends were approximated and a marking scratch made to indicate the location of the slot. Then the ends were elevated from the wound in turn and the slot cut with the ordinary electric saw.

It seemed to me that it was easier to apply this type of plate than the ordinary flat one, for when it was placed in the groove there was no tendency for it to move, and it was an easy matter to insert the screws. These screws, like the angle plate, were made of vitallium. They were long enough to penetrate the cortex on the far side of the bone.

After closure of the wound, simple coaptation splints were applied to the upper arm, and the patient for the first few days rested his arm on a pillow. He started movement of the fingers and hand almost immediately. He had a very comfortable convalescence, with practically no pain. He was out of bed on the seventh day with his arm in a sling. At this time motion was started at the elbow and shoulder joints, and was carried out daily in a gradually increasing degree.

The patient was discharged from the hospital on the eleventh postoperative day and complete active motion was present at the end of a

month. He returned to work in five weeks, and at the end of six weeks he had free motion of the entire injured extremity and was able to hold a very large book on his outstretched arm. The after-care of this patient was carried out under the direction of Dr. Hawley, and he will tell you of the things that he considers important in the convalescent treatment.

The advantages of the angle plate appear obvious. There is great strength of repair; shortened period of treatment and disability; early motion and function of the extremity; and comfort to the patient.

The early appearance of callus, and its evident strength were due to the abundant circulation provided by early motion.

GEORGE HAWLEY (Westport, Connecticut): It is a great pleasure to be here, to listen to these papers, and to meet so many old friends.

Dr. Patterson wished me to say a few words about the bone plate which he used in the case he has described.

Nineteen large dogs were used in the experiments at Yale. Twenty-three femurs were plated. Seven were failures, one was infected, and in six, the bone cracked and pieces fell out a few days after operation. A dog's femur is, however, not a good test object, because the cortex is thin and brittle.

Thirteen humans have been treated with the angle plate and fifteen bones plated. Four were fractures of the humerus, two fractures of both bones of the forearm, four of the tibia, three of the femur. It has been found that screws get the best hold when tight in the distal cortex and loose in the proximal cortex. To accomplish this, a small drill is used through both cortices and the hole in the proximal cortex enlarged with a carpenter's awl. The hold of the plate depends on the screws. Protruding screw ends cause no discomfort or sensation.

In the human cases up to the present, no screws or plates have become loose. There has been new bone deposit as shown in radiographs two weeks after operation. Callus formation has been steadily progressive, as evidenced in the *x*-rays. The plated bones have been strong and continued strong from operation until union was complete. There has been absence of pain and tenderness at the site of fracture after wound healing.

I would like to quote two short paragraphs from a paper soon to be published: "In conversation with a writer during a visit to his hospital in Compiègne during the war, Carrel expressed the belief that when the process of fracture repair is better understood, fractures would unite in less time than now. The thought was suggested that it might not be so much the need of methods or agents to stimulate fracture repair as removing inhibiting factors which regard repair and release forces now held in check.

"The principle of the mobilization calls for effective and continued immobilization of the broken bone ends. The more perfect the immobilization, the closer we come to fulfilling the principle of immobilization. There may be more significance than we imagine in the difference between perfect and imperfect immobilization. It is possible that the more absolute the immobilization, the more active and positive the process of fracture repair."

Notable have been the following facts: Absence of erosion and atrophy of bone around screws; uniform and rapid recalcification of the fracture; strength in the plated bone as tested clinically throughout the period of repair; patients' confidence of strength in the plated bone; difficulty in determining when bony union is complete and new bone strong and plate unnecessary.

No claim is made for anything new. Personally, I dislike the word "new" and try to avoid it.

KELLOGG SPEED (Chicago): I wish to say a word to establish the date of this procedure. This plate was first described by Dr. Souttar in 1911 or 1912. I used it in 1914, 1915, and 1916 in at least ten cases, some involving the femur, some the humerus, and some the tibia. It is very easy to insert and the cutting of the slot is a very simple procedure with a circular saw.

I agree with all that has been said about its additional mechanical aid in the stability of the fracture, and with what Dr. Hawley emphasized about the difference between near immobilization and complete immobilization being the factor which leads to the success acquired with this plate. I had no failures with it; I had no infections with it. I merely make this statement to set down that the plate was first described and used by Dr. Souttar.

R. ARNOLD GRISWOLD (Louisville): I am very much interested in Dr. Gurd's description of his method. We have used since 1933 a similar method which I learned from John Caldwell—the hanging cast—with excellent success. Our series of fractures of the humerus of all types treated with this kind of cast numbers from 250 to 300. We have had one nonunion in that list.

I have found a misapprehension in speaking to various people about the traction cast, especially in regard to the surgical neck fractures. The traction cast will reduce most fractures of the shaft; it will not reduce those above the deltoid insertion. If the surgical neck fracture is properly reduced by traction and manipulation, the hanging cast will hold it in position if the long head of the biceps is intact.

The most effective maneuver that we have found for the reduction of the surgical neck fracture in connection with the hanging cast is a method described by Dr. F. J. Cotton and Dr. Gordon Morrison in the *New England Journal of Medicine* in November, 1934. It has the same advantages that Dr. Gurd's method has, as they are very similar. I am glad to see the trend away from wide abduction in fractures of the upper third of the humerus.

EDGAR L. GILCREEST (San Francisco): I was very much interested in Dr. Gurd's paper. In numerous papers on fractures I have tried to emphasize that we should return to the more simple methods instead of the various complicated ones requiring more and more gadgets. In fact, I believe in years to come this period will be known as the era of gadgets in the treatment of fractures.

When I was with von Hocker in Gratz, Austria in 1913, they were using in his clinic a method that Dr. Gurd speaks of this morning, with the exception that a very ingenious piece of strong cardboard was folded under

the arm and up in the axilla. It was very light but kept the humerus, as Dr. Gurd has said, about 20 degrees from the chest. It was folded in such a manner that the forearm could rest on it. It is important now to have Dr. Gurd call this simple and effective method in the treatment of fractures of the upper two-thirds of the humerus again to our attention.

I hope that this Association for the Surgery of Trauma will in the future more and more emphasize to the surgical profession of America these fundamental and basic principles in the treatment of all kinds of trauma and lead us away from the complicated methods with which our literature is becoming filled.

FRASER B. GURD (closing): I would like to say that I perhaps did not sufficiently indicate how apologetic I felt at bringing before such a body a matter which seemed to be so simple, even moronic in character. However, I feel, as Dr. Gilcreest evidently does, that the danger has been on the part of many of us to make the treatment of fractures appear to be so complicated that the men who actually must treat the fractures throughout the country have been at a very serious disadvantage. I feel justified, therefore, in putting on the program a method which might be described by the adjectives "simple and effective."

THE PROBLEM OF THE UNUNITED FRACTURE

MELVIN S. HENDERSON, M.D.

Section on Orthopedic Surgery, The Mayo Clinic

ROCHESTER, MINNESOTA

UNUNITED fractures may be divided into two groups: (1) those in which the bones are merely delayed in uniting, evidence of attempts at consolidation being apparent; (2) those in which the fragments are in a fixed state of nonunion and no evidence of an attempt at consolidation is to be seen. The element of time cannot be used to place these fractures in one group or the other, for some fractures are clearly in a state of nonunion within the short period of three months after the injury, whereas others show evidence of efforts at repair a year or more after sustaining of the fracture. Failure to recognize this division has led to confusion in the evaluation of treatment, for measures that may suffice in delayed union will be inadequate and lead to many failures in nonunion. Experience has taught that any ununited fracture is a foe worthy of the surgeon's best efforts; he is dealing, in a delayed union, with a subnormal physiologic condition at the site of fracture and in nonunion with a state of physiologic inertia.

ETIOLOGY

It is not within the scope of this discussion to discuss adequately the etiology of these conditions but several points should be mentioned.

Sex is of no importance but age apparently is of importance. Why is the extremely resistant ununited fracture of the tibiae encountered among the newborn and infants? This fact cannot be readily accounted for, but probably some congenital anomaly of the blood vessels is accountable. It is possible that in some adults the blood supply to certain regions is congenitally poor and, on a fracture being sustained at these sites, union fails to develop. Except for fractures of the neck of the femur, ununited fractures are no more common among elderly than among younger patients.

Patients with ununited fractures are almost invariably in excellent general condition, and no clue as to cause can be elicited on the most painstaking general examination. The cause, therefore, must be local. A history of severe, traumatizing original injury often is given

by the patient with an ununited fracture; in such a case the insult to tissues may be so great that repair is slow to develop and, when it does develop, is unable to go on to completion. Interposition of muscle between the bone ends, the muscle later becoming a fibrous mass; inadequate reduction; faulty fixation; too early mobility and, in the lower extremity, too early weight bearing, are all prominent etiologic factors. In some few cases no cause can be ascertained; the bone simply will not unite although all conditions seem favorable. Bones differ in their shape and size, also as to the functional demands made on them and the manner in which stresses of force are transmitted through the sites of fracture. All of these have more or less bearing on the reason why a given fracture fails to unite. To my knowledge, no dependable figures ever have been presented to show the percentage of fractures that will fail to unite within the normal period of healing.

GENERAL CONSIDERATION OF TREATMENT FOR DELAYED UNION AND NONUNION

Regulation of diet and administration of glandular products or drugs are of no real help. It must be recognized that physiologic inertia exists at the site of fracture and that this must be done away with and the process of regeneration of bone initiated. In the treatment of ununited fractures, as in other conditions wherein surgical treatment is difficult, a great variety of opinions as to method are to be found. Because, for example, union in a case of ununited fracture of the tibia may result on weight bearing in a walking caliper, it may be argued that in all cases such treatment should be employed. Because delayed union of the fragments of a humerus occasionally is overcome after congestive therapy and massage, it is argued that such treatment should be used. Because, in another case, union takes place after injection of venous blood into the site of fracture, that type of treatment is advocated, and one could go on citing many more methods. Advocates of such lines of treatment never have reported any sizable series of cases and, on inspection, there is little to support the majority of the claims. The same criticism applies to drilling of the ends of the bones. All these measures have some merit and may turn the tide and stimulate formation of bone in the presence of delayed union, but, in my experience, they are absolutely futile against nonunion.

It may be asked how delayed union can be distinguished from nonunion. In the typical case of nonunion, pain and tenderness are absent and the roentgenogram indicates that the bone ends are

clear-cut and rounded. They lack the irregular, somewhat fuzzy, excessive formation of callus so often seen in cases of delayed union. Often a year or more has elapsed since the injury. Such fractures require operation. Any open operation which consists of freely dissecting away the fibrous tissue from about and between the bone ends, freshening and fitting them together, and providing internal fixation by metal devices and external fixation with casts or splints, will bring about union of many ununited fractures. Numerous reports have established without doubt that the autogenous bone graft gives the best results. Therefore, my discussion as to treatment will be confined to the use of the bone graft; I shall mention briefly the general technique and the more specific technique involved in treating several fractures of the more intractable types.

SOME ESSENTIALS FOR BONE GRAFTING PROCEDURES

Repetition is necessary in order to keep constantly before surgeons certain cardinal principles as to selection of cases, technique and after-care. They can be enumerated as follows:

1. No ununited fracture should be subjected to direct operative attack if there are any draining sinuses or if there is any latent infection in the vicinity of the fracture.

2. Fibrous tissue should be removed from between and about the bone ends; the medullary cavities should be opened, and the ends of the bones fitted, so that they can be held in close apposition by the aid of a bone graft.

3. The graft must be long and large enough to insure large surface contact of graft with both fragments. The bone graft serves two functions, a physiologic function in stimulating formation of bone and a mechanical function in providing internal fixation.

4. The graft must be held securely to the fragments by aid of beef bone screws, autogenous bone pegs, metal screws or metal bands. Multiple chips of bone should be packed along the line of fracture and as much as possible along the line of contact of the bone graft with the fragments. The more bone that is brought to the site of fracture the better.

5. External fixation, preferably by casts, must be provided for sufficient time to protect the graft during the period of "weakness," which develops about the fourth to the sixth week. This protection is particularly necessary in cases of fracture of the humerus or femur. Three months is the earliest that external fixation can be abandoned and some sort of protection is often essential for six months from the time of operation.

6. It must be constantly kept in mind that repair of bone is always slower to be induced after it once has failed. The second attempt at repair is certain to be slower in starting, developing and finishing than nature's first attempt. Because of that fact careful supervision of resumption of function, as to time, manner and amount, is the definite responsibility of the surgeon.

RELATIVE INCIDENCE OF UNUNITED FRACTURES OF VARIOUS BONES

In a review of the records of 583 patients with ununited fractures treated by bone grafting operation from 1912 to 1936 inclusive in The Mayo Clinic, the relative incidence as to the bones involved was as follows: tibia, 233 cases; humerus and femur, 100 each; radius alone, seventy; radius and ulna combined, forty-four; ulna alone, thirty; clavicle, five; and metatarsal, one.[5]

RELATIVE RESULTS IN TREATMENT OF FRACTURE OF DIFFERENT BONES

In 530 cases the end results were definitely determined. The results following bone graft of the tibia were the best in that in 94 per cent of cases the fragments united. Success was obtained in treatment of fractures of other bones as follows: the radius alone in 93 per cent of cases; the ulna alone in 89 per cent; the humerus in 86 per cent; the radius and ulna in 85 per cent and the femur in 78 per cent. Difficulties encountered in dealing with individual bones differ with the location of the fracture, be it in the upper, middle or lower third.

TROUBLESOME SITES OF FRACTURE OF VARIOUS BONES

The anatomic division of the various long bones into upper, middle and lower thirds is recognized, and it is interesting to study the end results on that basis.

Concerning the shaft of the femur, the results were equally good whether the fracture was in the upper or middle third, but if it was in the lower third the frequency of failure was higher. The percentage of good results relative to the tibia was lowest when the fracture was of the lower third. The bone in that region is smaller than it is elsewhere and surface contact of the bone consequently is less. Also, the bone of the lower third is more pipelike, has less blood supply and the surrounding structures are not so vascular as is true of the upper and middle thirds. Again, fractures of the lower third of the humerus gave more trouble than those of the middle and upper thirds and the

FIG. 1. Nonunion of neck of femur eight months' duration.

FIG. 2. Same case as that represented in Figure 1. Good alignment following ten days' traction.

results were relatively poorer than when the upper or middle third was concerned. The lower fragment is often short and the difficulty in preparing it for reception of the bone graft is great, thus necessitating

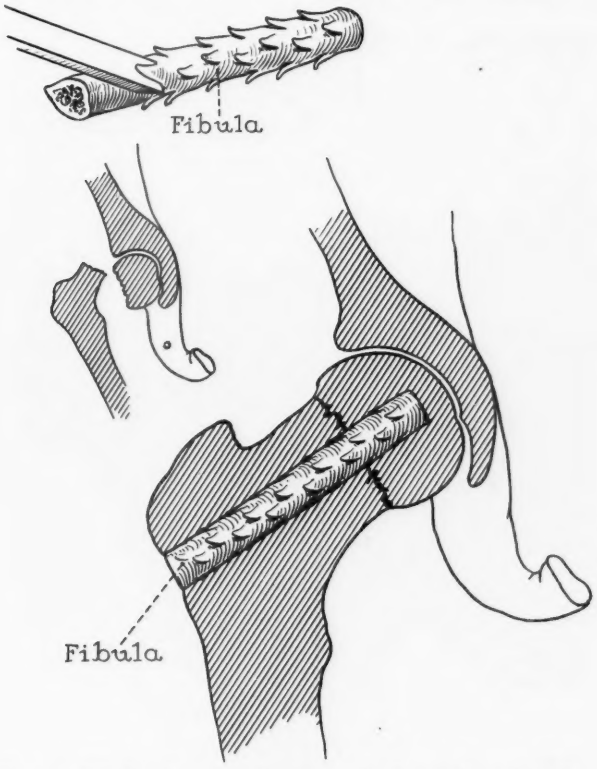

FIG. 3. Fibular bone graft cleansed of muscle and periosteum and roughened to permit more ready vascularization.

more dissection, manipulation and trauma. This is especially hazardous if operation has been performed previously with consequent formation of scar and, worse, if there has been infection. In cases in which the radius alone was involved, the percentage of failures was higher if the fracture was in the lower third than if it was in the middle or upper third, and the same was true when the ulna alone was involved.

When the operation was performed because of fractures of both the radius and ulna—in other words, because of a double fracture of the forearm—repair of fracture of the middle third gave the poorest results. In that situation, particularly in the presence of delayed union, there is often an attempt at synosteosis between the radius and ulna, necessitating extensive and time consuming dissection to remove the excessive callus. In some cases I am convinced it is better to perform the operation in two stages; first, to operate on one bone,

and after that has united to operate on the other bone. Such a procedure in two stages is objectionable from the patient's viewpoint but may be to his best interests.

FIG. 4. Same case as that represented in Figures 1 and 2. Union fourteen months after operation.

TECHNIQUE IN CERTAIN TYPES OF CASES

It may be stated that, other things being equal, the larger the graft and the greater the amount of surface contact of the graft with the fragments, the better is the chance of success. This has led me to emphasize what, at the clinic, we have called the "massive" graft,[2,3,4] which is of the same type that Campbell has aptly called the "onlay" graft.[1] If this type of graft were always referred to as the "onlay massive" graft, it would serve to emphasize the point that but little bone should be removed from the cortex and that the graft should be large.

Another point I wish to emphasize is that the packing of bone chips, and especially chips of spongy bone, about the site of fracture is of great importance. By using the massive graft, fixation is pro-

vided and the chips bring extra bone to the region where it is most needed.

Fractures of the Neck of the Femur. "The head of the femur must

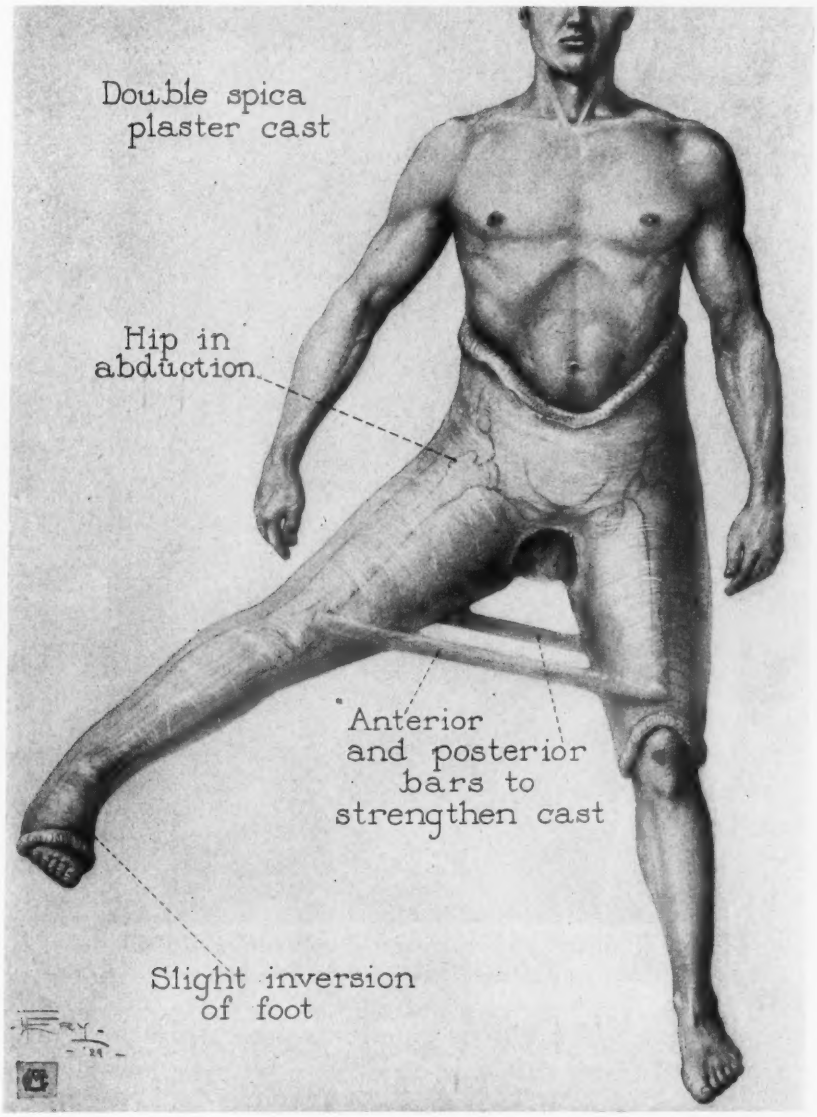

FIG. 5. Double spica cast.

be viable; there must be sufficient femoral neck left to work with; the fibrous tissue of the union must be dissected out, and the bone ends must be freshened and accurately fitted if the maximal results are to be obtained."[5] This is an excerpt from an article I published more than a year ago. With the exception of the remark about the

viability of the head and the amount of neck left I am not certain that statement is correct.

We have had some excellent results from "blind pegging" of the

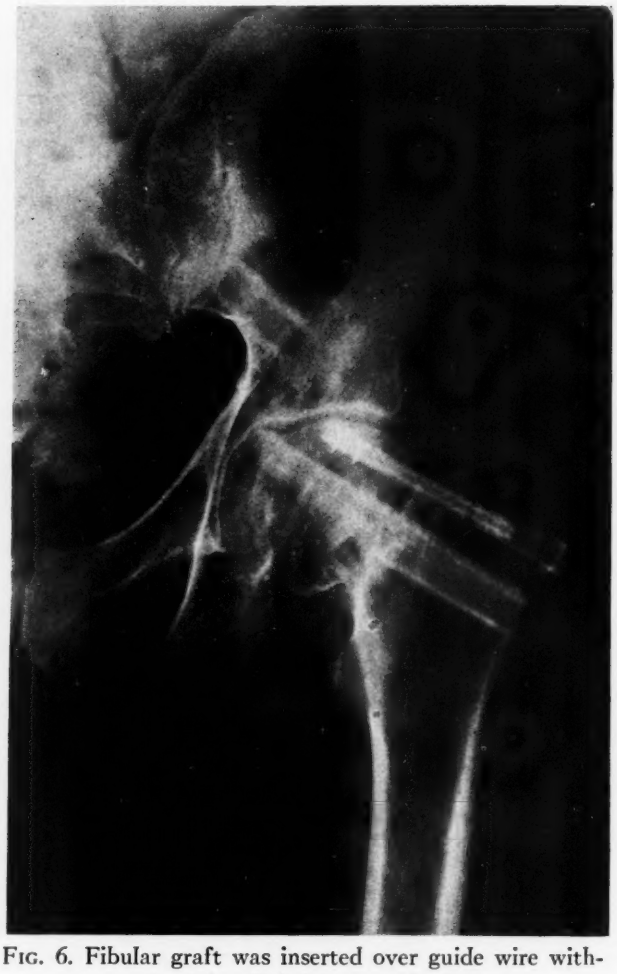

FIG. 6. Fibular graft was inserted over guide wire without opening joint. Reinforcement by lag screw.

fibula in cases in which fibrous union was present. In these cases by skin or skeletal traction it was possible to pull the lower fragment down and restore normal anatomic relationships (Figs. 1 and 2) with good alignment of the head and neck. A guide wire was inserted under roentgenologic supervision and verification; a drill of proper size was fitted over this wire and a hole was made through the trochanter and neck and well into the head. Then a fibular segment of proper length was inserted over the wire. The fibular graft should be thoroughly cleansed of all muscle, fascia and periosteum and it should be roughened with the aid of a chisel to insure ready penetra-

tion of blood vessels from the surrounding bone. (Fig. 3.) It is possible that the piece of the fibula acts as a physiologic stimulus to formation of bone and that the fibrous union develops gradually into bony

FIG. 7. Nonunion of humerus with typical angulation at site of fracture.

FIG. 8. Same case as that represented in Figure 7. Deformity corrected and fragments held with bone graft.

union. (Fig. 4.) In those cases wherein there is no fibrous union and the joint fluid plays about the surfaces of the fracture, this method probably will not be successful, for it is known that bone pegs inserted across joint surfaces tend to fracture at the joint line in cases in which they were used in the hope of inducing arthrodesis.

Postoperative fixation in a double spica cast is essential. Motion should not be permitted (Fig. 5) in less than three months and weight bearing should not be allowed until at least six months have elapsed.

In two cases, in addition to the bone graft, I have used a lag screw to help maintain fixation. In these cases (Fig. 6) results were happy and I was able to permit motion much earlier than in other cases. It must be remembered, however, that the head of the femur is small and poorly supplied with blood and that it will not remain viable when subjected to ruthless drilling.

Nonunion of the Lower End of the Humerus. In cases wherein the lower fragment is short, it is usually difficult, without undue trauma,

to expose enough of the fragment to allow application of the massive bone graft. Exposure is best carried out by an anterior external incision, keeping well anterior and medial to the musculospiral nerve. Too vigorous traction may produce paralysis of the musculospiral. The median nerve lies well to the medial side and, if exposed, should be gently held out of the way.

Once exposure is adequate, enough of the cortical bone on the anterior surface of the lower fragment should be chiseled away to produce fairly free bleeding. After the bone ends of each fragment have been sawed off squarely, so as to fit accurately, and the medullary cavities have been opened, the cortex on the anterior surface of the upper fragment should be prepared in the same manner as that of the lower fragment was prepared, care being taken that the prepared surfaces are in the same plane.

The next problem is fastening of the graft to the lower fragment. This can be done by inserting beef bone screws through the graft and opposite cortex. Vitallium screws can be used. If the cortices of the fragments are too osteoporotic to allow screws to be employed, use of Parham bands may be required. It is often necessary to tilt the lower fragment well out of the wound and then put in the graft. Next, the graft is brought into contact with the upper fragment, care being used that the bone ends are pressed firmly together, end to end, before the graft is fastened to the denuded area on the upper fragment. Then the bone chips from the denuded cortices, the clippings from the medullary surface of the graft and the scrapings of spongy bone obtained from the upper end of the tibia, just below the epiphyseal region should be carefully packed about the site of fracture. (Figs. 7 and 8.)

The arm should be included in a spica cast and not disturbed even for dressings for about eight weeks unless there is evidence of drainage from the wound.

SUMMARY

Ununited fractures can be divided into: (1) those in which there is still some attempt at repair of bone—delayed union; and (2) those which are in a fixed state of physiologic inertia—nonunion. The etiologic factors are local and not systemic. In cases of delayed union conservative measures may succeed in stimulating metabolism of bone at the site of fracture, but not in cases of nonunion. Operative measures, preferably the use of an autogenous bone graft, are necessary in the latter cases. Operation should not be undertaken in the face of draining sinuses or of evidence of inflammation. The bone

graft should be as large as possible and must be held firmly clamped to the fragments. Multiple chips of bone packed about the site of fracture are of great aid. Fractures of the neck of the femur can be dealt with successfully without arthrotomy in cases in which fibrous union has occurred. The method consists in overcoming the shortening with traction, securing anatomic alignment, and inserting a large piece of autogenous bone, such as a fibular segment of such length that it extends from the trochanter well into the head. This procedure could be called "blind" insertion. It probably is not suitable in cases in which no fibrous union is present; then open operation is preferable. Fractures of the lower end of the humerus are the most difficult of all humeral fractures to deal with and are best treated by the "onlay massive" graft.

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EXPERIMENTAL FAT EMBOLISM*

J. Dewey Bisgard, M.D. and Charles Baker, M.D.

OMAHA, NEBRASKA

REGARDING the importance of fat embolism as a clinical entity there exists much confusion. Both clinical and experimental evidences indicate that fat emboli occur frequently, particularly in association with trauma to bone. There is good evidence that, in adults, some fat is embolized with most if not every fracture and with most surgical insults to bone. But the frequency with which these emboli cause morbidity and mortality is the subject of controversy. For although many fatalities have been reported in which the presence of fat in the pulmonary capillaries has been the only demonstrable cause of death, it has been shown repeatedly that animals will tolerate without appreciable effect much larger quantities of fat injected intravenously than could conceivably enter the blood stream in clinical cases.

Buerger,[1] Pinner[2] and Flournoy[3] have reported cases of fat embolism in which ruptured and crushed subcutaneous fat was the sole demonstrable injury. Virchow[4] and Warthin[5] have reported fat embolism following childbirth and have explained the origin of the intravascular fat as that liberated from the pelvic fatty tissue by pressure from the fetal head while passing through the birth canal.

Numerous authors have stressed the fact that fat emboli are found not infrequently at post-mortem examination of patients in whom the cause of death was unrelated to trauma. Reports indicate an incidence in this group of 10 to 15 per cent. Such nontraumatic causes include chemical poisons such as phosphorus, potassium chlorate, corrosive sublimate, phenol, carbon tetrachloride, arsenic, and its derivatives used in the treatment of syphilis, alcohol and potassium cyanide, as reported by Grondahl,[6] Burns and Bromberg,[7] Puppe,[8] MacMahon and Weiss[9] and Winogradow.[10] Other nontraumatic sources include intravenous injections of medications containing oil and a wide variety of diseases such as diabetes, tuberculosis, post-influenzal pneumonia and pancreatitis. Carrara[11] found fat embolism present in 22 per cent of cases of cardiorenal disease. Thus one of the difficulties in evaluating the clinical importance of the relation of trauma to fat embolism becomes apparent.

* From the Departments of Surgery, Physiology and Anatomy, University of Nebraska, College of Medicine.

Injured bone is the principal source of massive fat embolism because in it are provided the three factors necessary to embolization of fat: (1) the presence of free fluid fat; (2) accumulation of this fat under pressure; and (3) the presence of open veins which do not collapse.

In bone marrow of adults there is an abundance of fat which, composed principally of olein, is liquid at body temperature. In children fat embolism is rare and this has been explained by Speed,[12] Landois,[13] Zwerg[14] and Timmer[15] by the fact that the bone marrow in children contains relatively little fat and the small amount present is composed of the more viscous palmitin and stearin.

The marrow held in a rigid bony enclosure can be placed under great pressure from hemorrhage and accumulated exudate. The veins supported by bone are prone, when severed, to remain open, thus able to receive the liquid fat under pressure.

If fat enters the blood stream in the majority of cases in which bone is injured one may well ask why symptoms of fat embolism are observed so infrequently. An explanation may be found in the results of the studies of Lehman and Moore,[16] who found that they could inject intravenously into a dog as much as 120 c.c. of cotton-seed oil without producing a lethal result. Since the femur in man contains approximately 65 c.c. of fat, it would appear by deduction that the quantity which enters the blood stream in most cases of fracture would be well tolerated. In the authors' experiments, reported below, several rabbits received all of the fat contained in a tibia and not one of them showed any evidence of ill effect. Gröndahl has stated that fat embolism is directly accountable for not more than 1 per cent of deaths associated with fractures.

Fat emboli are first filtered out in the pulmonary capillaries. If they are sufficient in amount to produce widespread blockage of these capillaries, cyanosis, dyspnea, pulmonary edema and hemorrhagic infarction occur. If they pass through into the general circulation they may be carried to all tissues in the body but they have little or no effect unless they lodge in the brain or heart. When they occlude cerebral or coronary vessels they produce congestion, thrombosis, hemorrhagic infarction and degeneration, and necrosis. The cardiac signs and symptoms are those of coronary occlusion. The changes in the brain give rise to headache, vomiting, delirium, increased or subnormal temperature, coma and convulsions.

Symptoms may appear within a few hours after the injury but usually do not develop until the third or fourth day. They have a cyclic tendency corresponding presumably to the periodic passage

or showers of emboli. A patient who is convalescing normally becomes restless and apprehensive; the respiratory rate increases, as does the pulse; dyspnea, cyanosis and a productive cough develop;

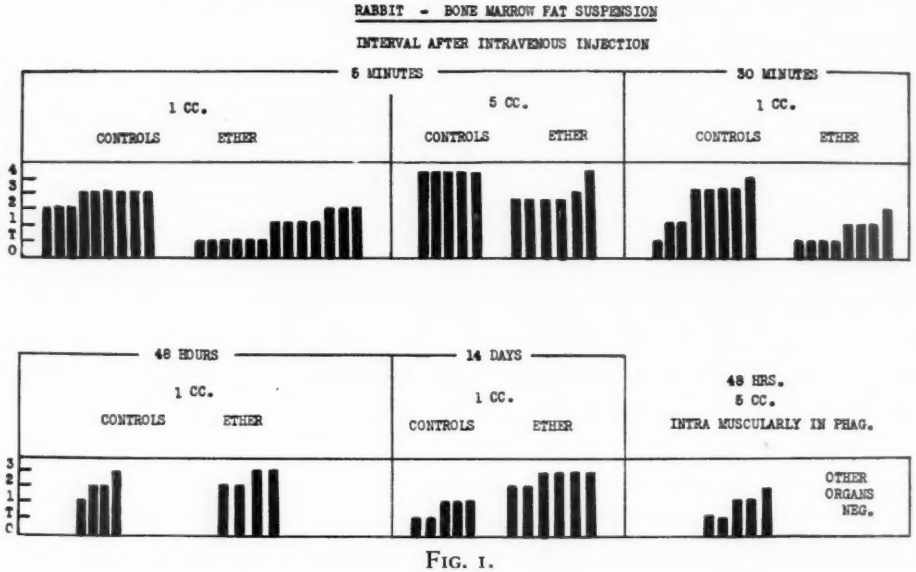

FIG. 1.

the blood pressure rises and later falls; the temperature may become subnormal or rise to extreme heights; or the symptoms may be predominantly cerebral, characteristically a delirium similar to delirium tremens.

When the symptoms develop within a few hours after injury or operation it often is difficult or impossible to differentiate fat embolism from shock which may also be present and to which fat embolism may be a contributing factor. When fat embolism appears days later the condition may be indistinguishable from pneumonia or delirium tremens. Undoubtedly fat embolism is a forerunner of pneumonia in some cases. Suggestive, though not pathognomonic, of fat embolism is the presence of fat in the sputum as demonstrated by Warthin and in the urine as pointed out by Reidel.[17] Fat emboli have been observed in retinal vessels with the ophthalmoscope.

Since there is no specific treatment, and as a matter of fact, no treatment other than supportive and symptomatic, efforts in management should be directed to prevention of the entrance of fat into the blood stream.

Caldwell and Huber[18] have shown experimentally that the presence of a tourniquet during and for some time following operation or manipulation of bone greatly reduces the incidence of and the quantity of fat emboli. Caldwell and Huber also found that the

incidence and extent of fat embolism in their experimental animals was influenced greatly by the activity of their animals following operation and therefore recommended immobilization and fixation

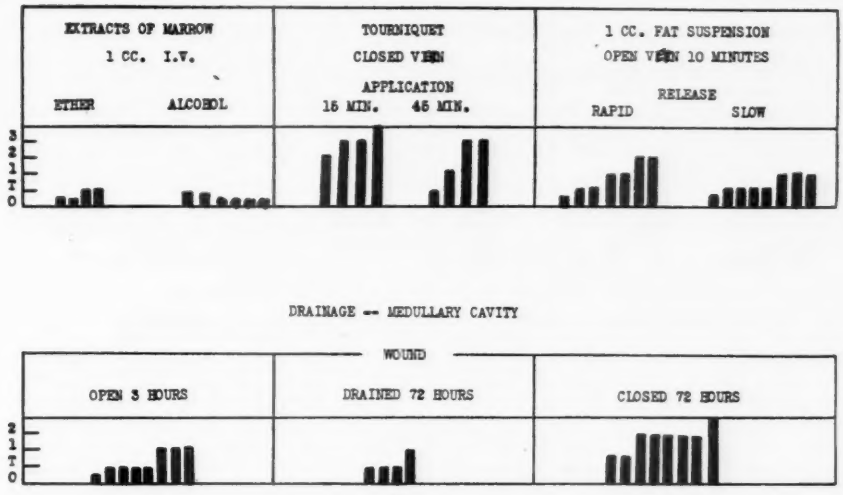

FIG. 2.

and liberal sedations. Gauss[19] demonstrated that the presence of fat increased the viscosity of the blood and the likelihood of thrombosis. It has been suggested therefore that dilution of the blood with salt solution was a feasible procedure. Reicket[20] believed that elevation of an extremity decreased embolization of fat.

In an endeavor to study the influence of certain factors, such as anesthesia, the tourniquet and drainage, upon fat embolism and to collect data which might be helpful in lowering the incidence of this complication in clinical cases the experiments described below were carried out.

EXPERIMENTAL DATA

Rabbits were used for the experiments and bone marrow fat from rabbits was used for emboli. The fat was obtained by removing all bone marrow from both tibias of rabbits used only for this purpose. The marrow was macerated in a mortar and mixed with salt solution. It was then drawn into a syringe and injected into other rabbits intravenously (in one group it was injected intramuscularly). The anesthetized animals were killed by lethal etherization and those that had recovered from anesthesia and the controls, or non-anesthetized ones, by pithing. The segments of lungs and other tissues removed for microscopic examination were excised behind hemostats before the heart ceased beating and were immediately placed in

formalin to fix them before the fat in the capillaries could be washed out with the escape of blood.

All tissue sections were studied and graded. They were graded or classified upon a basis of the quantity of intravascular fat and of the number of capillaries containing fat in a representative member of low power microscopic fields. Gradations ranged from a trace (one or two collections in an entire section) to four (many vessels packed with fat in each low power field). Since an evaluation of the contained fat by this or any other method is at best merely relative, the experimental results must be interpreted accordingly. However, since a high degree of consistency prevailed in the interpretation of specimens obtained from animals subjected to the same experimental procedures, the findings as interpreted have very definite comparative value.

The experiments dealt with varied aspects of the problem of fat embolism and are grouped accordingly.

Group I. The Influence of Fat Solvent Drugs. Since the few cases of fat embolism observed by one of us (J. D. B.) occurred in patients who had received either no anesthesia or an anesthesia containing no ether and since ether is a fat solvent, the possibility that ether might have a beneficial protective influence in avoiding the catastrophe of fat embolism was suggested. To investigate this possibility equal quantities of bone marrow fat were injected into veins of the ears of two groups of rabbits. One group, after receiving the injections, had the anesthesia continued for varied periods, as outlined below. The other group served as controls, receiving no anesthesia.

1. Specimens recovered five minutes after completion of injections. The etherized animals continued to receive ether during this period and then were killed by increasing anesthesia to a lethal level. The average fat content of the lungs of the twelve etherized rabbits was 1; a trace in five, 1 in four and 2 in three. In eight non-etherized controls, the fat content average was 2.6; 2 in three and 3 in five. Thus there was definitely much less fat in the etherized than in the non-etherized group.

This difference was observed in the first few animals examined and the question of cause suggested itself. Did the ether break down the fat or did it dilate the capillaries so that the fat globules could pass from the pulmonary into the systemic circulation? If the latter were the answer fat should be filtered out in the capillaries of other organs and found in sections of those organs. Consequently in five of the etherized and in four of the non-etherized animals sections were cut from segments of the liver, spleen, kidney, myocardium and

brain. In no instance was fat found in the vessels of any of these organs.

2. Specimens recovered thirty minutes after injection. The average fat content of eight etherized rabbits was 0.85 as contrasted to 2.3 in eight non-etherized. Again there was a striking difference and again no fat was found in the kidneys, spleens, myocardiums, livers or brains of any of the animals.

3. Specimens obtained forty-eight hours after injection. In the animals killed forty-eight hours after they had received 1 c.c. of a fat suspension intravenously the averaged fat content of the lungs was: in the four which were etherized while receiving injections, 2.5; in the four control non-anesthetized, 2.0.

Thus, after forty-eight hours the lungs in both groups contained approximately an equal quantity of fat.

4. Specimens obtained fourteen days after injection, as in (3) with the exception of the time interval between the injection of fat and the recovery of specimens. In the six animals which had been etherized while receiving injections the fat content of the lungs averaged 2.6 while in the five non-anesthetized controls the averaged content was less than 1.0 (0.7). The spleen, kidney, liver, heart and brain of each animal contained no fat emboli.

Curiously, the fat remained unabsorbed longer in the etherized animals.

5. Massive intravenous injections. Each rabbit in this group received intravenously all of the marrow contained in one tibia of a donor rabbit (used only for this purpose). The macerated marrow when injected was suspended in 5 c.c. of salt solution. The lungs were recovered thirty minutes after the injections. The average fat content was 2.7 in the etherized animals and 5.0 in the non-etherized.

As in the case of the animals which received the smaller quantities of fat, a much smaller amount was found in the lungs of the etherized animals but, as would be anticipated, there was much more fat in the lungs of all the animals which received the massive injections. No fat emboli were found in the spleen, liver, kidney, heart or brain of these animals.

6. Injections of bone marrow fat dissolved in 1 c.c. of ether. Since ether is rapidly volatile, considerable difficulty was encountered in making the injections. All animals died while receiving them, presumably of gas embolism. By thoroughly pre-chilling the ether it was possible to complete the injections before the onset of convulsions. In four animals which received complete injections there was no fat in the specimens of lungs examined in two and only traces in two.

7. Injections of bone marrow fat dissolved in 1 c.c. of 95 per cent alcohol. Six rabbits received intravenously bone marrow dissolved in 1 c.c. of alcohol. Three of them were killed twenty minutes later and three after twenty-four hours. No fat emboli were found in four animals and only traces in the lungs of two, both of these after twenty-four hours.

Group II. Influence of Tourniquet. In this group of experiments a tourniquet was applied to the hind leg of each animal as near the trunk as possible and 0.5 c.c. of the fat suspension injected into an exposed superficial vein. No anesthesia except local infiltration of the skin at the site of exposure of the vein was used.

1. Closed vein. In eight animals the veins remained intact except for the puncture wound made by the needle, and the injected fluid could escape only through the small vessels which were cut in exposing the vein which was injected.

In four the tourniquet was released fifteen minutes after completion of the injections and the animals killed twenty minutes later. The average fat content of the lungs was 3.0. In the remaining four the tourniquet was released after forty-five minutes with the result that the average fat content was only 1.75.

2. Open vein—rapid release of tourniquet. Eight rabbits received injections as in the preceding series, but after the completion of the injections the vein in each animal was opened by dividing it. In the blood which escaped droplets of fat could be seen.

In the four rabbits in which the tourniquet was released after fifteen minutes there was an average fat content in the lungs of 1.25 and in the four in which the tourniquet remained in place for forty-five minutes only 0.75.

3. Open vein—gradual release of tourniquet. The eight rabbits in this series were treated as were those in the preceding series with the exception that the tourniquet was released gradually, permitting rather profuse bleeding to take place for a short period of time.

In all of the animals of this series there were only traces of intravascular fat, and there was no appreciable difference in the quantity present in the lungs of animals subjected to ten or forty-five minutes of vascular occlusion.

Group III. Influence of Drainage of Wound. In each of the twenty rabbits under local infiltration anesthesia the tibia was exposed and a large hole drilled into the medullary canal. Through the hole a small flexible probe was introduced and the marrow agitated.

In eight animals the hole in the cortex was left open as was the wound; in four it was drained with a Penrose wick and in the other

TABLE I

Group I. Influence of fat solvents.

A. Ether inhaled.

(*a*) 5 minutes after intravenous injection of 1 c.c. of fat suspension.

12 etherized rabbits—T.–5; 1–4; 2–3; av. 1.0.

8 non-anesthetized—T.–0; 1–0; 2–3; 3–5; av. 2.6.

(*b*) 30 minutes after 1 c.c.

8 etherized rabbits—T.–4; 1–3; 2–1; av. 0.85.

8 non-anesthetized—T.–1; 1–0; 2–2; 3–4; 4–1; av. 2.3.

(*c*) 48 hours after 1 c.c.

4 etherized rabbits—T–0; 1–0; 2–2; 3–2; av. 2.5.

4 non-anesthetized—T–0; 1–1; 2–2; 3–1; av. 2.0.

(*d*) 14 days after 1 c.c.

6 etherized rabbits—T–0; 1–0; 2–2; 3–4; av. 2.6.

5 non-anesthetized—0–1; T–1; 1–3; av. 0.7.

(*e*) 5 minutes after 5 c.c. (massive injection).

6 etherized rabbits—T–0; 1–0; 2–4; 3–1; 4–2; av. 2.7.

5 non-anesthetized—T–0; 1–0; 2–0; 3–0; 4–0; 5–4; av. 5.0.

(*f*) Immediately after intravenous injection of fat dissolved in 1 c.c. of ether.

4 rabbits—0–2; T.–2; av. 0.25.

B. Alcohol—after intravenous injection of fat dissolved in 1 c.c.

95 per cent alcohol.

20 minutes, 0–3.

24 hours, 0–1; T.–2.

Group II. Influence of Tourniquet.

A. Closed vein, intravenous injection 0.5 c.c. fat suspension.

(*a*) 15 minutes after.

4 rabbits—0–0; 1–0; 2–1; 3–2; 4–1; av. 3.0.

(*b*) 45 minutes after.

4 rabbits—T–1; 1–1; 2–0; 3–2; av. 1.7.

B. Open vein—rapid release—tourniquet

(*a*) 10 minutes.

4 rabbits—0–0; T–1; 1–1; 2–2; av. 1.25.

(*b*) 45 minutes.

4 rabbits—0–1; T–1; 1–1; 2–1; av. 0.75

C. Open vein—gradual release.

(*a*) 15 minutes.

4 rabbits—0–1; T–2; 1–1; av. 0.5.

(*b*) 45 minutes.

4 rabbits—0–0; T–2; 1–2; av. 0.75

Group III. Influence of drainage after trauma to marrow.

A. Open wound.

(*a*) After 3 hours.

4 rabbits—0–2; T–2; av. 0.25.

(*b*) After 72 hours—0–0; T–2; 1–2; av. 0.75.

B. Closed wound—bone sealed with bone wax.

(*a*) After 3 hours.

4 rabbits—0–0; T–0; 1–1; 2–3; av. 1.75.

(*b*) After 72 hours.

4 rabbits—0–0; T–0; 1–1; 2–2; 3–1; av. 2.00.

Group IV. Intramuscular injection of 5 c.c. of fat suspension.

After 48 hours, 5 rabbits—T–2; 1–3; av. 0.8.

eight the hole was sealed with bone wax and the wound tightly closed. In both series half of the animals were killed three hours after operation and half after seventy-two hours.

The average fat content of the lungs of those with drained and open wounds was 0.25 (a trace in three and none in two) in three hours, and 0.75 (a trace in three and 1 in one) in twenty-four hours.

In the sealed series there was definitely more intravascular fat. After three hours there was 1.75 and after twenty-four hours slightly more, 2.00.

Group IV. Influence of Trauma to Bone with Removal of Bone Marrow. The lungs from seven of the donor rabbits or those from which bone marrow had been taken and used for intravenous injections in other animals were examined for the presence of fat emboli. In each rabbit the medullary cavity had been widely exposed and most of the marrow removed. None had received an injection but all had been anesthetized with ether. In four, specimens were obtained thirty minutes after operation and showed no fat in three and a trace in one. Three were killed three days after operation and in the lungs of all three were found traces of intravascular fat.

It is difficult to explain the small number of fat emboli in this series of animals. Probable factors of influence were the extensive removal of marrow, and the free opening of the marrow cavity.

Group V. Intramuscular Injections of Marrow. In five rabbits 5 c.c. of a marrow fat suspension were injected into the muscles of the thigh and the lungs removed forty-eight hours later. Fat was found in phagocytes in the capillaries and in alveoli in all specimens. Quantitatively there was one in three and only a trace in two.

Thus it appears that the liquid fat in the soft tissues was transported to the lungs and presumably transported by means of phagocytes.

Group VI. Normal Rabbits. Since it has been reported that not infrequently the capillaries of the lungs of rabbits normally contain fat, an extensive search was made of the lungs of five normal untreated rabbits and in no specimen was intravascular fat found.

DISCUSSION

The first group of experiments shows that the fat solvents, ether and alcohol, definitely diminished the quantity of fat, demonstrable by fat stains, in the pulmonary capillaries. In the blood within the lungs ether existed in sufficient concentration to have this influence upon the injected fat. The failure to demonstrate fat in the capillaries of tissues in the circuit of the general circulation indicates that the

absence of fat in the pulmonary capillaries is not merely the result of diminished filtration from dilatation of the capillaries by ether. The fact that after elimination of the ether the lungs of the etherized animals contained more fat than the controls seems unreasonably paradoxical. An explanation has been formulated by Lehmann and Moore who obtained similar results in a similar group of experiments. They believe that ether injected or inhaled dissolves and holds the fat until it (ether) is eliminated. The fat therefore is redeposited in the pulmonary capillaries where the ether is given off. Furthermore they have demonstrated that ether, inhaled or injected in a dog after a fatty meal, resulted in the presence of globules of fats in the pulmonary capillaries. This may explain the greater quantity of fat in the etherized animals forty-eight hours after injection. The experiments in group II gave rather conclusive evidence that obstruction of the venous return flow with a tourniquet diminished the number of fat emboli and that washing the vein by releasing the constrictor to a point that reëstablished arterial circulation without releasing venous obstruction further reduced the number of these emboli.

Decompression of the marrow cavity and free drainage diminished the number of emboli. Presumably this prevented the accumulation of fat under pressure.

CONCLUSIONS

The results of these experiments indicate that:

1. Ether anesthesia has little or no beneficial influence upon embolization of fat, and if at all, only during anesthesia or while it is present in the blood stream in moderate concentration. It could have no effect upon the fat which enters the blood stream four or five days after injury or operation.

2. The use of a tourniquet during operations upon bone and the gradual release with some venous bleeding before complete release may lessen the incidence of immediate fat embolism.

3. The prevention of increased pressure by drainage of the medullary canal and wound is probably one of the most important preventative measures. The obvious objection to drainage in clinical cases is the possibility of inducing infection along the drainage tract. As judged from the experience of one of us (J. D. B.) this danger is very remote if drainage is continued not longer than four days.

4. Manipulation of injured bone should be gentle and minimal.

5. Immobilization and elevation reduce the likelihood of emobilization of fat.

6. Fat in the sputum and in the pulmonary capillaries is not pathognomonic of fat embolism. It may arise from liquid fat in the soft tissues transported to the lungs in phagocytes.

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DISCUSSION

Albert H. Montgomery (Chicago): We have had the pleasure of listening to a very interesting paper on a relatively rare subject. This matter of fat embolism presents many paradoxical phases. In the first place, pathologists will tell you that about half of the patients going to autopsy will show fat embolism in the lungs. It is well known that many of these cases are unassociated with trauma. The question, then, of the pathologic diagnosis of essential fat embolism must be associated with the clinical phase of the subject. It must be due to trauma for a pathologic clinical recognition of fat embolism to be possible.

It has been interesting to note that in the diagnosis some of the same things hold true, namely, the similarity to shock in the early phases, and the similarity to delirium tremens and alcoholism in the cerebral cases. Although it may occur early, it should not be forgotten that a good basic rule is that given, I believe, by Dennis some years ago, that shock occurs within the first three hours, fat embolism within the first three days, usually between the fifty-sixth and seventy-second hour, and pulmonary embolism about the third week.

There have been many diagnostic factors employed to strengthen this matter. One of them is, of course, the estimation of fat in the blood. It has been found, however, that the average physiologic chemist is unable to give an accurate report that would help to produce a definite conclusion.

Finding fat in the urine is of value, but it must be remembered that fat will float on the urine and that unless the last portion of the urine emptied from the bladder is examined, the urinary examination may be misleading.

In 1877 it was suggested that dark field illumination of the blood might show fat droplets larger than red blood corpuscles. This has been shown experimentally to be of value. Blood removed after the injection of sterile oil has been found by dark field illumination to show large particles of oil in the blood.

More recently Jirka and Scuderi from the County Hospital, Chicago, have shown that as early as twenty minutes after the intravenous injection of oil, *x*-ray films of the chest will show definite shadowing which they consider as probably indicative of fat embolism.

There is very little to the active treatment, but I think there is considerable to the preventive treatment.

These factors have all been covered by Dr. Bisgard in his paper. Stress should be laid, however, upon the traumatic handling of the bones. In other words, as Lexer pointed out, use sharp electric cutting instruments rather than chisels and mallets in doing this work, whenever possible. The use of a tourniquet appears to me a little questionable, especially as it has been suggested to leave it on about an hour after the completion of the operation. I wonder whether it would not be wiser to do without the tourniquet and risk the chance of a possible fat embolism, seeing that it is fatal in only a few instances.

Experimentally, it has been shown that animals can build up tolerance so that they will take many times the lethal dose of fat. What is it that does this? Possibly some emulsifying agent or perhaps some digestive ferment. Some observers have suggested that work along an experimental line might show some agent of that type that could be used in the treatment of fat embolism, and possibly prolong life where fat gets into the circulation.

Dr. Bisgard deserves considerable credit for this paper. A piece of investigation of this kind will, we may hope, stimulate other work of like nature. We shall probably always have plenty of clinical material on our programs. Research work and investigations of interest to this Society should be encouraged.

EUGENE J. BOZSAN (New York City): I merely wish to pass on to you the observation of three cases in which I believe fat embolism occurred following the use of high speed electric drill. Two cases were observed after a large-sized drill was driven through the lower end of the femur, and a third when it was used in the neck of the femur. Infarct of the lung occurred, verified clinically and by *x*-ray examination.

These rapidly spinning large-sized drills have perhaps driven by centrifugal force droplets of fat into the veins, causing the embolism.

This group of cases is, of course, too small for any basic conclusions, but some note may be made of it.

J. DEWEY BISGARD (closing): I first wish to thank the discussers for the additions they have made to my paper. In regard to the ratio of

frequency of fat embolism in operated and non-operated cases: I have seen six cases, four of which have been proven, and in the other two the evidence pointed in that direction. Of the six, three were cases that were operated upon, two of them trisacral fusions and one an open reduction. The other three were patients who had had non-operative manipulations. One operated case occurred just four weeks ago, a case in which I had done a trisacral fusion. On the second day the patient's temperature suddenly went up to 106.5, but yet all the clinical signs were inconsistent. She appeared quite well, was rational and her pulse rate was only 100. In other words, the clinical evidence did not check at all with the febrile response, and it appeared that there was a disturbance in the medullary centers regulating heat, presumably upon the basis either of anesthesia with the perivascular changes that go with anoxia or of fat embolism. I think that the symptoms resulted from fat embolism. In three days the temperature returned to normal, and since then the patient has gone along perfectly well.

SIMPLE ANTERIOR DISLOCATION OF THE ELBOW JOINT WITH RUPTURE OF THE BRACHIAL ARTERY

CASE REPORT

JAMES A. JACKSON, M.D.

Jackson Clinic

MADISON, WISCONSIN

ANTERIOR dislocation of the elbow joint is an exceedingly rare injury. Simon[1] in 1931, in a review of the literature, stated that Hippocrates first mentioned the condition and added that it may be fatal in a few days. The first case recorded was by Evers in 1787. Simon's own case brought the total then recorded to thirty-one. In 1932, Christopher[2] reported a case. R. Bonn[3] and G. A. Oddone[4] each reported a single case in 1931 and 1932. My own case brings the present number to thirty-five. Included in this list are ten cases where fracture of the olecranon tip was present, a condition not properly included in this series. Excluding these, there are twenty-five cases of true anterior dislocation.

When this rare injury is complicated by rupture of the brachial artery (mine is the only one on record) the surgeon is presented with a combination of injuries that will require his immediate attention and skill, since if not promptly treated the condition may result in gangrene, amputation, and even loss of life.

In the case herewith reported, my nephew, Dr. Reginald H. Jackson, Jr., was present in the operating room with his movie camera and obtained a complete graphic record of the two lesions.

In a series of cases of posterior dislocation of the elbow with vascular injuries reported by Eliason and Brown,[5] the extremity became gangrenous due to the lack of early recognition and institution of surgical care; one patient died, and one case resulted in ischemic contracture.

While Simon in his article on anterior dislocation does not mention rupture of the brachial artery as a complication, he notes that Richet reports one autopsy and that three amputations are reported by Canton,[6] Morel Lavalle, and Rigaud. In all probability, the circulation was interfered with in these cases. This complication, if met today and promptly recognized and treated by immediate surgical interference should give better results. Marnham[7] reports a

successful termination in a case of posterior dislocation where prompt incision with evacuation of the blood clots and ligation of both ends of the divided artery resulted in saving the arm. As in our

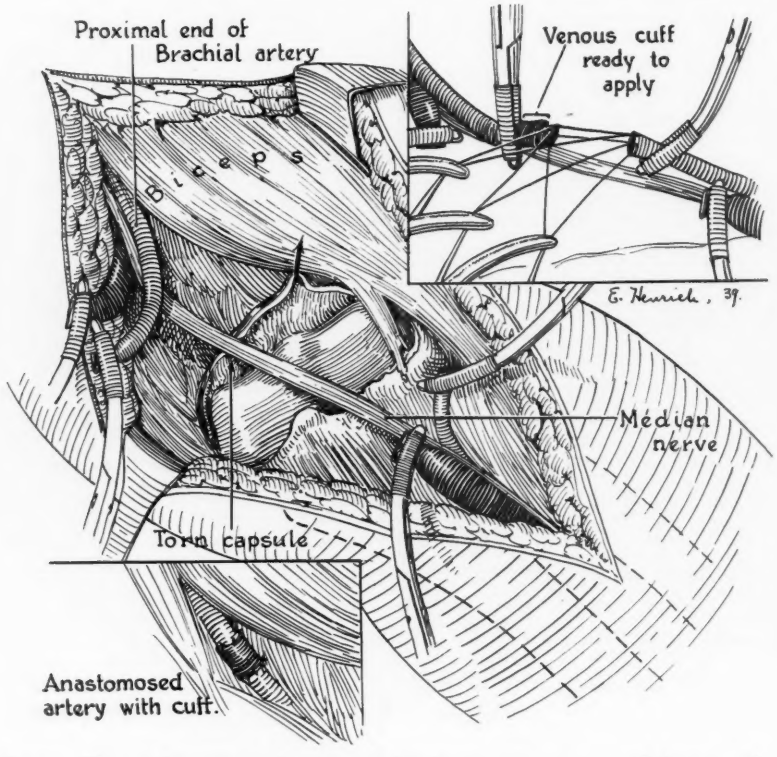

FIG. 1. Shows the ruptured artery and vein, transverse tear of the capsule of the joint, intact median nerve, intact biceps tendon. Inserts—anastomosing the artery with a venous cuff for reinforcement.

case, the median nerve and biceps tendon were intact. It may be that the anastomosis of the artery in our case was not the determining factor, but it was most encouraging to note the pulsations and the return of color after the continuity of the artery was restored. I have been unable to find a record of any other case in which an attempt was made to anastomose the artery at the time of operation.

On August 2, 1938, E. D., a robust white male, fell a distance of 4 feet, striking on the back of his flexed left elbow. Intense pain and marked swelling with deformity of the joint were present almost immediately following the accident. He was referred to the Jackson Clinic and was seen by me within fifteen minutes of his fall. Swelling in the cubital space was more than one would expect in such a short period of time since injury. The whole forearm was bluish-gray in color and cold. There was only slight sensitivity to pinprick and there was complete absence of the radial pulse.

X-rays revealed an anterior dislocation of the elbow joint which was promptly reduced on the *x*-ray table, but there was no return of radial pulsation. The patient was taken to his room and pavaex treatment,

FIG. 2. August 2, 1938. Simple anterior dislocation of the elbow joint. Note that there is no fracture of the olecranon connected with this dislocation.

including the arm and forearm, was instituted. Since close observation for a period of two hours revealed no improvement in the circulation, the patient was referred for surgery with a diagnosis of probable rupture of the brachial artery with resulting hematoma and loss of circulation in the extremity.

An anterior incision was made over the elbow joint; after evacuation of about ½ pint of clotted blood, the exact nature of the traumatic lesion was revealed. (Fig. 1.) The anterior portion of the joint capsule had been torn completely across, exposing the glistening cartilaginous lower end of the humerus with the intact median nerve lying directly upon it. Both ends of the torn and separated artery, and also of the torn brachial vein were exposed to view. The proximal end of the artery was pumping a stream of blood. The flexor muscles attached to the internal epicondyle had been severed at their attachment and the brachialis anticus muscle was likewise torn in two. The ends of the artery and vein were clamped, and it then occurred to me that an anastomosis of the artery might be feasible. The clot in the distal end of the artery was removed by suction, and a ½ inch

cuff taken from the vein was slipped over the artery. Anastomosis was performed with interrupted and running sutures of fine Chinese silk, the cuff of vein reinforcing the junction. For a moment there was some balloon-

FIG. 3. November 30, 1938. Show loss of 10 degrees flexion.

FIG. 4. Shows loss of 65 degrees extension; full supination present.

ing and hemorrhage at the point of anastomosis, but with slight pressure of the finger tip, this shortly subsided and soon stopped completely. There followed an almost immediate return of color in the hand and the radial pulse at the wrist was now faintly palpable.

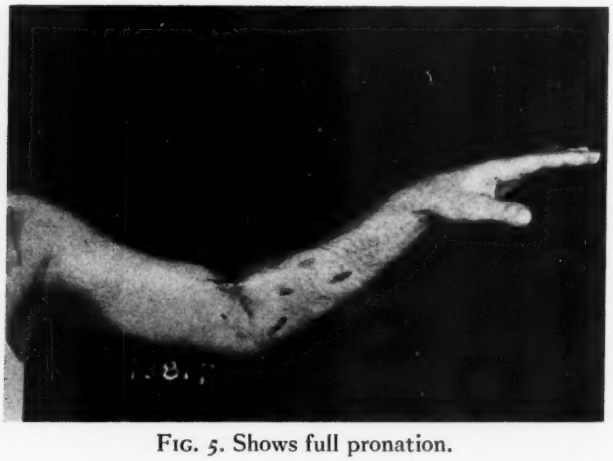

FIG. 5. Shows full pronation.

The joint capsule was closed with interrupted sutures of chromic catgut and the torn muscles were likewise repaired. The field was flushed with saline and the skin united with dermal. Many puncture incisions were made through the skin and fascia of the forearm to allow the serum to exude and prevent a possible ischemic contracture. The arm was dressed and put up in a position of extension with elevation of the extremity.

Eight months following the operation, the patient had a strong radial pulse with no trophic disturbance in the hand, a loss of flexion of 10 degrees and of extension of 65 degrees (Figs. 2, 3, 4 and 5), but was able to do heavy labor without discomfort. Since the roentgenograms show no bony obstruction to motion, the rather large loss of extension is probably due to shortening of the anterior portion of the capsule which occurred in overlapping it in repair. Extension could undoubtedly be increased by a capsulotomy and fascial graft.

CONCLUSIONS

1. Rupture of the brachial artery should always be suspected in injuries of the elbow joint, and especially in dislocations accompanied by absence of the radial pulse and change in color of the hand.

2. Prompt diagnosis with immediate surgical interference is necessary if the extremity is to be saved.

3. Successful anastomosis of the ruptured artery is feasible and greatly lessens the possibility of ensuing gangrene in the extremity.

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DISCUSSION

Edgar L. Gilcreest (San Francisco): We have had a series of most interesting papers before this Association, but no paper has emphasized more forcibly than this paper of Dr. Jackson's that the object of this Association is to bring back to the fold the well-trained surgeons who may have wandered off into narrow specialties.

The presentation of this case shows so clearly how, in cases of trauma, we need a surgeon who has had broad training. He may not know whether he is going to deal with a fracture, with a joint involvement, or with vascular or nerve surgery.

Dr. Jackson was fortunate in having seen this patient so early. That is most unusual. He is to be congratulated on his early recognition of what

the problem was, on his courage in exploring immediately and, finally, on his ultimate result.

GORDON M. MORRISON (Boston): Cases of this type are as scarce as the proverbial hen's teeth. In ten years at the Boston City Hospital (slightly over 2,000 beds) we have had one lacerated wound of a branchial artery, and that was caused by a sharp implement and not by a dislocation.

It seemed to me that it might be worthwhile to say a word or two about the differential diagnosis that presents itself in a case of this type. Swelling of the arm near or above the elbow, pulse gone, anesthetic cold hand, may be rupture of the brachial artery, or it may be pressure hematoma from a fracture at or near the elbow joint, as described so ably by Stephen Jones two or three years ago.

Still another condition—and it has chanced that I have operated on two such patients—is that of midshaft fracture of the humerus with pressure hematoma so severe that the brachial artery was cut off, giving a picture quite similar to that described so well by Dr. Jackson. The color of arm and hand in his case was bluish-gray. In the two cases of midshaft humerus fracture with pressure hematoma which I saw, the hand was pale and white, as it was in a supracondylar fracture in which I did a fasciotomy. This difference in color is merely of passing interest.

The value of multiple punctures through the skin and fascia, which I think we were all taught ten, fifteen and more years ago, is, to my way of thinking, controversial and of doubtful value in the arm. It would seem that fasciotomy of that part of bicipital fascia called lacertus fibrosus, under which the artery dives, is the one method of attack that really is efficient. However, that is controversial.

CARLETON MATHEWSON, JR. (San Francisco): About two years ago I was walking through one of our emergency hospitals and chanced to look into the operating room to find an alcoholic lying on the table with a dressing over his right arm. The interns explained that he had been picked up off the street about fifteen minutes before, that he had a laceration in the right cubital fossa, that his hand was cold and his radial pulse was missing. The patient was taken to surgery without *x*-ray examination. Exploration of the wound in the cubital fossa revealed an anterior dislocation of the elbow through a compound wound in the brachial fold. There was a clean transverse laceration in the brachial fold extending down to the exposed lower end of the humerus. Further exploration revealed that the brachial artery had been completely severed and that the anterior portion of the capsule had torn loose from its lowermost attachments. There were no other structures torn. The wound was debrided carefully and we were able to accomplish an immediate end-to-end suture of the brachial artery.

As in Dr. Jackson's case, the radial pulse returned immediately. We made no attempt whatsoever to repair the anterior portion of the capsule, simply reduced the dislocation and put two or three skin sutures in the transverse laceration, dressed the wound, and returned the patient to the

ward. The radial pulse remained palpable for four days. On the fourth day it became very weak and on the fifth day disappeared entirely. On the eleventh postoperative day the pulse in the radial artery returned. During the period the circulation to the hand, which had returned immediately after suture of the artery, remained unimpaired. We believe that the artery became thrombosed after the fourth day and that in the meantime a collateral circulation had developed, sufficient to maintain proper circulation in the extremity. When the patient left the hospital at the end of the third week, he had good circulation in the hand.

Unfortunately, we were unable to follow this patient. We had hoped to obtain an arteriogram to demonstrate what had happened, but the patient signed his release from the hospital at the end of the third week and did not return. Strangely enough, he had almost complete return of flexion and extension in the elbow joint at the time of his discharge.

FREDERICK J. TEES (Montreal): Before I congratulate Dr. Jackson on the splendid results that attended his treatment in this case, I should like to supplement what Dr. Gurd's thanks for the hospitality shown to us, and to say how much we appreciate the opportunity of coming down and joining in the activities of this Association.

It seems rather curious, in view of the great rarity of the condition Dr. Jackson describes, anterior dislocation of the elbow joint, that Dr. McKim, who has been sitting beside me, reminds me of a report that we made ten years ago in which we together described two cases and in which we referred to a prior case which I had published in 1923; Dr. McKim tells me that last year he had a fourth case.

The interest in our cases, in view of what we have heard today, was that in no one of the four cases concerned were there any serious nerve or vessel complications. The difficulty with the first case, though, was that we could not reduce the dislocation. We were led to believe from the textbooks available that the reduction of an anterior dislocation of the elbow joint was the simplest thing in the world. One simply had to put it back; but we worked in vain. Under an anesthetic we all had a try at it, and it refused to go back. Finally, we had to expose it, and what we found was this: that the whole lower end of the humerus had button-holed through a longitudinal slit in the triceps tendon. With the joint exposed it was quite a simple matter to reduce the dislocation and the patient had no further complications.

Dr. McKim's case of last year was identical with that, in that here, too, the end of the humerus had button-holed through the triceps tendon.

ALBERT H. MONTGOMERY (Chicago): In connection with injuries about the elbow joint, it is interesting to consider the possibility of traumatic arterial spasm. I have seen two cases that occurred in supracondylar fractures with closed reduction; when they were put up, the radial pulse was absent, the hand began to get white and then cold. Removal of the restraining apparatus did not restore the circulation, and of course the immediate

thought was that in the manipulation the brachial artery in some way had been injured. In both cases it was cut down upon, but in neither instance was a thrombus found. The artery was not opened, and in both cases, one after one day and the other after two days, the circulation was gradually restored. We were rather glad that we did not try to be such good surgeons, and open them up for resuture.

JAMES A. JACKSON (closing): After these interesting discussions there is little left to be said about the subject. This is a rare condition, but I hardly believe it is so rare as we think. Some of the cases are probably missed.

RUPTURE OF THE SPLEEN

AN ANALYSIS OF TWENTY CASES

JOHN M. FOSTER, JR., M.D. AND DUVAL PREY, M.D.

DENVER, COLORADO

THIS report comprises a review of twenty cases of traumatic injuries to normal spleens, the cases reported being those occurring in four Denver hospitals during the years from 1927 to 1938, inclusive. The authors appreciate the fact that the current and past medical literature contains numerous articles pertaining to this subject, nevertheless a study of ruptured spleens is always a timely one, particularly in view of the increasing incidence of such accidents resulting from our present mechanical age. Statistics indicate that rupture of the liver is a far more common accident than is traumatism to the spleen, but from a purely surgical viewpoint splenic ruptures are more important, because extensive damage to the liver is frequently so rapidly fatal that surgery cannot be attempted. The diagnosis in such cases is determined only at post-mortem examination.

ETIOLOGY

Rupture of the spleen is produced by violence of different kinds, and, furthermore, the type seems to vary somewhat in different communities. For example, Dretzka reported a series of cases in Detroit, the center of the motor industry, in which, surprisingly enough, gunshot wounds were the predominating factor, while in our own series the automobile exacted the highest toll, 15 cases, or 70 per cent. Of the remaining six cases, five followed falls and one was caused by a stab wound.

Conforming with other statistics, there was a preponderance of males in the proportion of 9:1. The average age of the victims was 20 years, the oldest being 43 and the youngest 5 years of age. In this series almost one-half of the patients were younger than 15, which bears out Connor's contention that the recklessness of youth and the inability of youngsters to care for themselves in the presence of danger is a very definite contributory factor in the etiology of this accident.

SYMPTOMS AND SIGNS

The symptoms and signs in splenic ruptures have been so often and so accurately described that any review must seem superfluous,

but the fact remains that only too frequently surgery is delayed unnecessarily long because of failure to arrive at a correct diagnosis. In the present series of cases it was discovered that several of the patients were explored with an indefinite preoperative diagnosis of "possible or suspected rupture of a viscus."

Of the symptoms abdominal pain was, of course, outstanding, having been the admitting and chief complaint in every instance. The character of the pain varied in different individuals, but for the most part was described as generalized and in only 30 per cent of the cases was the discomfort localized to the left half of the abdomen. Pain referred to the left shoulder (Kehr's sign), described so frequently, was remarkable by its absence. The next most constant finding was tenderness which was found to be present in all save one case, but similarly was not localized in the majority.

TABLE 1
SYMPTOMS AND SIGNS IN ORDER OF FREQUENCY

	No. of Cases	Percentage
Pain	20	100
Pain localized	6	30
Tenderness	19	95
Rigidity	17	85
Localized to L.U.Q.	3	15
Shock	13	65
Dullness	10	50
Vomiting	7	35
Distention	3	15

Shock, of a greater or lesser intensity, should be an almost constant finding in any case of splenic rupture with the exception of those rare cases of delayed hemorrhage. In our review, rather profound shock existed in thirteen, or 65 per cent of the cases, and when present was an important aid in diagnosis. Syncope or unconsciousness was described in only a single instance. This, we believe, is a vastly overemphasized sign, in spite of Quenu's belief that syncope is pathognomonic of splenic rupture if delayed.

Regarding the importance of vomiting as a symptom, there is a considerable difference of opinion—some authors believing that this symptom is so common in most intra-abdominal diseases that its presence is not particularly significant; but on the other hand certain men (Connor, Robitshek, Trendelenburg, and others) feel that vomiting occurs frequently enough in rupture of the spleen to be a sign of some importance. The average incidence in various

series of case reports seems to be approximately 20 to 25 per cent, while our figures were somewhat higher; i.e., vomiting occurred in seven of the twenty cases (35 per cent).

Rigidity, generalized or limited, was encountered in eighteen of the twenty cases, but unfortunately from the point of view of diagnosis, in only three cases was the rigidity localized to the left upper quadrant. Dullness, a sign of equal or greater importance was described in 10, or 50 per cent, of the cases, while shifting dullness was elicited in only four. In our opinion, attempts to determine the presence or absence of dullness in the flank have been sadly neglected, for there can be no doubt that such a positive finding is the most important single clue to correct diagnosis and early intervention.

White blood counts preoperatively were done in fourteen instances, the average count being 14,500 cells per cu. mm., which conforms quite well with reports from other clinics. It is our feeling that the white blood count is of relatively little diagnostic value unless in excess of 20,000, when, under such circumstances, hemorrhage may be suspected. Red cell counts were done so infrequently that no statement can be made regarding their value.

The presence of associated injuries in this analysis did not present the usual grave complications so frequently described, and in only one case (rupture of the spleen with rupture of the left lobe of the liver) could the fatal outcome be even in part attributed to other injuries. However, in addition to the above case, the following complicating injuries were noted: fracture of ribs (three cases); penetrating wound of the liver (one case); laceration of the diaphragm (one case); and contusion of the left kidney (one case).

DELAYED HEMORRHAGE

Delayed hemorrhage, an unusual but extremely dangerous complication of splenic traumatism, has received but scant attention in the past, and our present better understanding of this subject has been largely made possible by the splendid contribution of McIndoe, who, in 1932, collected and carefully reviewed forty cases of secondary hemorrhage following injuries to the spleen. Gardiner, in 1935, reported an additional case and remarked that there were fewer than fifty such cases in the literature, and since that time there have been only rare further case reports.

Despite the obvious infrequency of delayed hemorrhage, a thorough appreciation of its significance and a suspicion of its

possible presence must be constantly borne in mind, because the secondary hemorrhage is frequently so rapid in its onset and so copious in amount that surgery is unavailing. In support of this we find that McIndoe in his review states that there were seven patients who died of secondary hemorrhage before operative intervention could be attempted.

Delayed hemorrhage is not to be confused with a slowly progressive hemorrhage from a small tear in the spleen. In the former, there must be a definite latent period or a so-called period of "symptomatic silence." Arbitrarily, delayed hemorrhage is spoken of as such only when this latent period is in excess of forty-eight hours —statistics indicate that secondary bleeding occurs most often between the third and seventh days.

Some worthwhile facts are obtained from a study of the reported cases of delayed hemorrhage. In the first place, the initial trauma is usually of a less severe nature, which in part accounts for a certain lack of careful observation during the latent period. McIndoe and others believe that there are certain clues to diagnosis during this asymptomatic interval. The two most important diagnostic signs, according to these authors, are the persistence of dull, remittent left upper quadrant pain, and slight localized rigidity. It is of interest that secondary trauma was not a causative factor in the initiation of the delayed hemorrhage, for most cases occurred with the patient at rest or after slight straining, such as might occur from bending over or during the act of defecation. Furthermore, when the secondary hemorrhage started, in the majority of the cases its onset was very abrupt and immediately followed by the classical signs associated with primary rupture of the spleen, namely, severe pain, rigidity, tenderness and shock, and thus the indications for early operation were perfectly apparent.

Numerous authors (Neck, Demoulin, Nast-Kolb, Jackson) have attempted to explain the pathology in the spleen which might account for delayed hemorrhage, but the most satisfactory summary is again obtained from McIndoe's review. Apparently in one-half of the cases the secondary hemorrhage was due to rupture of a subcapsular or intrasplenic hematoma, while the remaining 50 per cent were found to have a walled off perisplenic hematoma which for one reason or another suddenly ruptured into the general peritoneal cavity. The author further calls attention to the anatomic structures in the left upper quadrant which help nature wall off a perisplenic hematoma, the ones of chief importance being: the diaphragm above; the splenic flexure below; the stomach, intestines,

and gastrocolic ligament to the right; the parietal wall laterally and behind; and the omentum and anterior abdominal wall in front.

In the present series, one of the authors (J. M. F.) had occasion to treat one case of delayed hemorrhage (three days) in which the patient recovered after a stormy convalescence following surgery. Because of the scarcity of such cases, it seems warrantable to report this one in some detail.

A boy of 13, while running, tripped over a low wire fence, fell forward and struck his chest and abdomen. He was transported to the Denver General Hospital and *x*-rays of the chest, were taken. Since these were negative, he was released and allowed to go home. He remained at home the same day and the next, the only complaint being mild colicky pain in the left upper quadrant.

He was first examined by me at his home thirty-six hours after the accident and at this time did not appear to be acutely ill. The temperature was 98.4°F., the pulse rate 68. The lungs were clear throughout and examination of the abdomen revealed only slight tenderness in the left upper quadrant. There was definitely no spasm, rigidity, or dullness in the flank. The following afternoon the pain recurred and became gradually worse during the night, and early the next morning he vomited coffee ground material. At the time of my examination at 9:00 A.M. the patient was obviously suffering a great deal, the temperature was 99.6°F. and the pulse rate 85. There was marked rigidity and dullness of the left side of the abdomen. The hemoglobin was 80 per cent, red blood cells 3,500,000 per cu. mm., and white count 12,500, polymorphonuclear cells 92 per cent. Rupture of the spleen with delayed hemorrhage was diagnosed and immediate operation was advised and accepted.

Through a left rectus incision more than a pint of blood was evacuated. The bleeding originated from a laceration of the superior pole of the spleen and could be nicely controlled by pressure. Therefore two gauze packs were inserted to this area and the abdomen closed in layers, using double suture material and six silkworm gut retention sutures.

On the eighth postoperative day the two gauze packs were removed without difficulty and without hemorrhage, but twelve hours later the boy complained of pain in the wound, his pulse became more rapid, and he vomited once. Inspection of the wound revealed fresh blood on the dressing and a diagnosis of secondary hemorrhage from the spleen was made. At operation there was no evidence of splenic hemorrhage; the bleeding was due entirely to wound disruption which was repaired without drainage, using interrupted heavy silk sutures through all layers.

The immediate convalescence, with the aid of a small transfusion, was essentially uneventful for a further period of eleven days. Then the patient developed symptoms of partial obstruction which was confirmed by *x*-ray. A third operation through a right rectus incision disclosed a mass of matted

together coils of small intestines which were carefully freed. Due to the poor condition of the patient a resection was considered inadvisable, and a jejunostomy was therefore done through a stab wound incision and the abdomen closed in layers without drainage.

Following this last procedure the drainage from the jejunostomy opening was profuse but finally ceased. Five weeks postoperatively the patient was discharged from the hospital. He has been carefully followed for a period of nine years, has been entirely well, and has shown no evidence of recurrence of obstructive symptoms.

TREATMENT

The foremost consideration in the treatment of splenic rupture is to determine the proper time to operate. One of the major errors seems to be difficulty in arriving at the correct diagnosis early, which may result in a serious delay and materially reduce the individual's chance of survival. In our series, the shortest interval between admission and operation was one hour, the longest sixty hours, while the average interval was twelve hours. However, in those cases terminating fatally, the average interval was only 7.5 hours, so early operation is by no means the entire answer. Certainly surgery should not be contemplated upon the patients evidencing signs of severe systemic shock, for in this type of case, careful preoperative preparation to combat the shock is essential.

The use of transfusions prior to surgery is of vital importance and is a greatly neglected adjunct to the shock treatment. Most authors extol the merits of transfusion, but in almost every instance its use is reserved for the postoperative phase. In the six fatal cases of this review, preoperative transfusion was instituted in only one patient and certainly there was ample time before operation (average of 7.5 hours) to have secured a suitable donor. Furthermore in the remaining fourteen favorable cases, preoperative transfusions were given in but three instances. To go a step further regarding the infusion of blood this seems a fitting place to call attention to the invaluable benefits of autotransfusion during surgery. It has only been comparatively recently that this life saving maneuver has begun to receive its proper recognition in this country, although Theis in Germany first suggested its advantages in 1914. Downing and Larsen in 1934 reviewed the literature pertaining to this subject and concluded that autotransfusion was a perfectly safe procedure, and since that time sporadic case reports (Reuton, Kraft and others) have appeared in which retransfusion in splenic rupture was accomplished without incident and with material benefit. In this series autotransfusion was carried out in only two instances—in

both patients with success and with a favorable outcome, due in a large part, we feel sure, to this procedure. Unfortunately, autotransfusion was not attempted in any of the fatal cases.

The type of surgery to be used depends to a certain extent upon the individual case. We are not in accord with certain authors who are so emphatic in stating that splenectomy is the sole method of treatment, although we are inclined to agree with McIndoe that removal of the spleen is the only method applicable in cases of delayed hemorrhage.

In the vast majority of cases splenectomy remains the procedure of choice for several reasons, among which may be mentioned: (1) the bleeding is immediately controlled and with less chance of secondary hemorrhage, (2) there are distinctly fewer postoperative intra-abdominal complications, and (3) it is the only method applicable in ruptures involving the large vessels at the hilus. Removal of the spleen was performed in twelve of our twenty cases, with four deaths, a mortality of 33.3 per cent. (Table II.)

TABLE II
OPERATIVE PROCEDURES

Type of Operation	Lived	Died	Per Cent Mortality
Splenectomy	8	4	33.3
Suture	2	1	33.3
Tamponade	3	1	25.0
Suture and tamponade	1	0	0
Total	14	6	30.0

Splenorrhaphy or suture of the spleen has only a limited field of usefulness and is to be used only in selected cases with small tears, due to the friability of the splenic tissue and the consequent difficulty of obtaining thorough hemostasis. This method was successful in two of the three cases in which it was attempted (Table II) in this series. Although most authorities condemn this type of operation, Dretzka is more enthusiastic and in 1930 reported ten patients in whom suture or suture and tamponade was accomplished with only two deaths, but it is of interest to note that more than 50 per cent of his cases were due to gunshot or stab wounds, such lacerations naturally favoring splenorrhaphy.

It is evident from a study of various case reports that tamponade has been used somewhat extensively in the past and some authors

(notably Barnes, Wallace, Rose, and Brogstitter) have gone so far as to state that it is almost the ideal treatment in ruptures, with the exception of those of the hilus. On the other hand, however, there are four tenable objections to the treatment by packing: (1) the spleen is too mobile successfully to pack a bleeding part; (2) the removal of the pack frequently will produce further hemorrhage; (3) the risk of infection; and (4) the danger of adhesions is materially increased.

In spite of the fact that tamponade was performed in four cases in this report (Table II) with only one fatality, it is our feeling that there is only a single indication for this procedure, namely, in the desperate risk patient in whom the general condition is so critical that it is obvious to the surgeon that any attempts at extirpation of the spleen would spell disaster. Under such circumstances there are a few cases saved by tamponade which otherwise would undoubtedly terminate fatally. Such a case was seen by the authors. Very briefly the history is as follows:

The patient, a man of 30, was attacked in September, 1928 by an unknown assailant with a knife. He immediately collapsed and was transported to the Denver General Hospital, where he was seen within an hour after the accident. Physical examination revealed a well nourished man in extreme shock, with ashen gray facies, subnormal temperature and extremely rapid, weak pulse. The abdominal examination showed an incised wound 7 inches in length, extending transversely beneath the left costal margin from the epigastrium to the tip of the eleventh rib. Almost the entire stomach, which did not seem to be injured, had herniated through the wound.

The man was immediately transferred to the operating room, where a saline infusion was started, and he was prepared for operation. After reduction of the herniation of the stomach, more than a liter of fresh blood escaped from the wound. The stomach, transverse colon, splenic flexure, and left kidney showed no evidence of damage, but there was a good sized rent in the lower pole of the spleen complicated by a laceration extending through the diaphragm into the left pleural cavity. Since the patient was pulseless, the idea of splenectomy was abandoned, and two 5 yard rolls of gauze were inserted as packing into the left hypochondrium, the free ends being brought out at the lateral angle of the wound. Six interrupted heavy silk sutures were inserted through all layers to approximate the wound edges. The immediate condition for several days was very critical due to a complicating left-sided pneumonia of traumatic origin, but after ten days, the packing was gradually removed, a little each day, following which recovery was uneventful.

COMPLICATIONS

The two most common complications in this series were wound disruption and intestinal obstruction. (Table III.) Evisceration has occurred so frequently following operations for ruptured spleens that Bailey suggests that this complication may be due to digestion of the suture material by pancreatic ferments. Whether or not this theory is correct, the fact remains that disruptions are frequent enough to consider replacing the usual wound repair with the use of interrupted braided silk sutures through all layers, a procedure which has been extremely satisfactory in our hands and has the twofold advantage of preventing disruptions and also of saving operating time at the conclusion of the procedure when a few minutes may mean the difference between success or failure. Of the two patients in this report showing evisceration, one recovered following resuturing but only after a stormy convalescence, while the other, with a disruption on the tenth postoperative day, subsequently died of peritonitis on the fourteenth day.

TABLE III
COMPLICATIONS

Nature of Complication	No. of cases	Died
Intestinal obstruction	2	1
Evisceration	2	1
Mastoiditis	1	0
Empyema	1	0
Total	6	2

Intestinal obstruction likewise was a complication in two patients, and again with one recovery and one death. As stated previously, we believe that intra-abdominal adhesions and obstructive symptoms occur more frequently following tamponade, although in this series the obstruction followed tamponade in one case and splenectomy in the second, with the fatality in the latter case.

Because of the close relationship of the spleen and the left lower lobe of the lung, pneumonia or pneumonia with empyema has been one of the more common complications encountered in the literature, but in the present report there was but a single instance in which this complication was present.

SUMMARY

1. A detailed analysis is made of twenty operated cases of splenic rupture observed in four Denver hospitals during the years from 1927 to 1938, inclusive.

2. It is felt that the correct diagnosis is not made frequently enough and, more particularly, not early enough. The two especially diagnostic signs of rupture of the spleen are localized abdominal rigidity and shifting dullness.

3. Associated injuries in this review played only a small part, and in our opinion there was but a single fatality attributable to injury other than that to the spleen.

4. The importance of delayed hemorrhage following splenic traumatism is recognized in spite of the infrequency of its occurrence. The etiology, pathology, symptomatology and treatment of secondary hemorrhage is discussed and a single case observed by one of the authors is reported in detail.

5. Preoperative transfusion and autotransfusion are life saving procedures which have not received proper recognition in our own series of cases or in those of others.

6. The treatment of choice in the vast majority of cases is splenectomy. Suture alone is indicated only in rare, selected cases with small lacerations, such as occur following gunshot or stab wounds. Tamponade, we feel, should be resorted to only in the desperate risk case in whom any other type of surgery would undoubtedly cause an operating room death.

7. Because evisceration is one of the most common postoperative complications, it is suggested that the usual wound repair be replaced with the use of interrupted heavy silk sutures through all layers.

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DISCUSSION

Roscoe C. Webb (Minneapolis): I have enjoyed Dr. Foster's presentation and have been very much interested in his contribution. There are a few points which I would like to discuss.

In connection with diagnosis we frequently read about Ballence's sign, referring to the increased splenic dullness due to the accumulation of blood clots about the splenic area. In this same connection an *x*-ray may be very useful. The *x*-ray may not only show cloudiness in the region of the spleen, but also, as in a recent case of my own, elevation of the diaphragm on the left side and displacement of the stomach toward the right side. The *x*-ray might also reveal a rib injury.

Dr. Foster referred to the frequency of injuries of the spleen occurring in younger patients. It is quite probable that this is due to the more elastic overlying chest wall of children.

I should like to bring up the question of spontaneous recovery of injured spleens for the consideration of this organization. In the numerous papers on ruptured spleens the cases are frequently divided into four groups: first, those who rapidly succumb and never rally; second, those who recover from the initial shock and present signs of a ruptured spleen; third, those who present signs of delayed hemorrhage two or more days following the initial injury; fourth, patients who are diagnosed as having ruptured spleens but recover spontaneously. I wonder if any of them ever recover spontaneously or if we are justified in considering spontaneous recovery as possible. As long as spontaneous recovery is unqualifiedly listed in the published articles we are apt to be led toward conservatism, and conservatism in the presence of rupture of the spleen is apt to be disastrous. Turnbull of London is quoted as saying that he never had seen at necropsy a spleen containing the scar of an old injury. James S. McCartney recently reviewed 25,000 autopsy records performed by the University of Minnesota Department of Pathology from 1920 through 1937 and found no instances of healed splenic hematomas. E. T. Bell's experience has been the same. It would therefore appear that spontaneous recovery should only be mentioned with qualifying remarks.

The cases of splenic rupture with delayed hemorrhage are very rare, as Dr. Foster has mentioned. I would like to mention the case of an 8 year old boy who was struck by a puck while watching a hockey game in February, 1939. He complained of pain and was carried home by his father. He was up and about the next day and did not present severe symptoms until the fourth day when he was leaving school. While putting on his coat he had an attack of pain in his left side and he vomited. I saw him one week after injury. His symptoms and signs were classical and on splenectomy the spleen was found to be lacerated at the junction of the upper and middle thirds on the outer surface, and there were two subcapsular hematomas. A transfusion of 300 c. c. of blood was given both before and after the splenectomy. Recovery was uneventful.

Herbert H. Davis (Omaha): Dr. Foster has presented an excellent review of a fairly uncommon lesion. My discussion is based upon the review of histories of eleven cases of ruptured spleen, five from the University of Nebraska Hospital and six from various doctors in Omaha.

As Dr. Foster reported, the automobile accident is a fairly common cause. Four out of our eleven were due to this and all the mortalities fell in this group. Two were the result of coasting accidents, the patients being brought into the hospital within a few minutes of each other. One was in a youngster with hemolytic icterus. His mother, one of his brothers and a sister had had splenectomy and another brother is planning upon having a

splenectomy this year. Probably the hemolytic icterus has something to do with making that spleen more liable to rupture.

Eight of our patients were males and three females.

Dr. Foster did not find left shoulder pain in the records of any of his cases. We would expect it to be fairly common because any irritation of the central portion of the diaphragm is likely, reflexly through the phrenic and supraclavicular nerves, to cause this symptom. In our cases, six of the eleven had definite left shoulder pain. In only one was it stated that there was no pain. In the other four it was not mentioned. I think if the people who had taken the histories had been on the lookout for this, we probably would have found more cases with that symptom.

Fullness in the flank is also a symptom, especially when there is a very severe hemorrhage, and should certainly be looked for. Percussion of the spleen will often give us a clue that we would not otherwise get.

Six of our cases had complete rupture of the spleen with severe intra-abdominal hemorrhage. A subcapsular or localized hemorrhage was in four, and delayed rupture, with delayed hemorrhage in one.

This latter case may be reported in a little more detail. A woman, age 38, received in an automobile accident a blow over the left chest which was followed by pain in the left upper quadrant of the abdomen and left shoulder. She vomited once. She did not see a doctor until the next day. He strapped her chest, thinking she had a thoracic lesion. The following day she went back to her work in a laundry and worked right along until the fourth day after the accident when at ten in the morning she had sudden severe pain in her left upper quadrant and epigastrium which soon became generalized. Nausea and collapse ensued. That evening she was taken to the University Hospital, where the chief findings were her pallor, air hunger, marked generalized abdominal pain and tenderness, inaudible peristalsis, and dullness in both flanks. The pulse was 132, blood pressure 118/78, hemoglobin 25, and white count 12,600. She was given a blood transfusion and operated on. At operation the spleen was found to be literally blown to pieces. Part of it was clear down in the pelvis. That which was left was just mushy, and no real splenic tissue could be made out. The hemorrhage was so severe that the surgeon packed the wound, and stopped the hemorrhage in that way, but the patient died ten hours later.

The suggestion comes to my mind that if these cases have symptoms of splenic lesion, it might be a good plan to keep them in bed to lessen the possibility of delayed hemorrhage.

WARREN H. COLE (Chicago): My experience with splenic rupture has been limited to a few cases, but I do wish to emphasize one or two points. One of them is the difficulty one frequently encounters in attempting to suture lacerations of the spleen. The spleen commonly is so mushy that sutures will not hold; attempts to apply sutures usually result in more

hemorrhage. I think it is well worthwhile not to waste time trying to suture these lacerations if it appears obvious that splenectomy may be quite simple. Splenectomy in patients with spleens that are normal except for the laceration, usually is quite easy. The only real contraindication is the serious condition of the patient. Moreover, these spleens are occasionally so badly pulverized that it is not worthwhile to try to save them, not nearly so necessary as it would be in laceration of the kidney where function is necessary for life.

I am also impressed with the danger of postoperative hemorrhages; a further etiologic factor is that, following trauma, thrombosis of the various veins may occur and progress to such a degree as to occlude a major trunk of the splenic vein. This may lead to a very marked edema and congestion of the spleen. From experimental and clinical findings we know that rupture of the spleen may then occur spontaneously.

I wish also to emphasize the use of autotransfusions. I know it is not used enough. True enough, one may be able to find a donor rapidly, but all of us will admit that the blood of patients when spilled in the peritoneal cavity should not be wasted; if a few hundred c.c. can be salvaged, it should be put into sodium citrate solution and used as a transfusion. I have resorted to this procedure in two instances. In one of these patients there were a lot of clots in the peritoneal cavity. It has been said that autotransfusion of blood salvaged from partially clotted blood is associated with a danger of severe reactions. However, I have heard of the use of such blood on several other cases, but in no instance, including my own, did a reaction occur. If an intestine has been perforated in addition to the splenic hemorrhage, the blood may obviously be contaminated, and should then be used only in dire emergencies.

Kellogg Speed (Chicago): I promised Dr. Foster to discuss his very excellent paper. May I modestly report seven cases of ruptured spleen in which I have operated. Three were gunshot wounds, two were coasting accidents, and the others were falls from a height.

I merely wish to touch upon a few practical points. Where the patient is in shock and there is undoubtedly a hemoperitoneum, one may be in doubt what organ is involved. You may not be able to find by palpation in the flank that the kidney has been injured, but in two of my cases the liver and the kidney on the opposite side were ruptured, and in one case the kidney on the same side was ruptured.

In one case I opened the abdomen, and finding some of the blood clotted, I did a Heller's test with nitric acid, believing that if there were free bile from the ruptured liver, I would have a key as to the exact location of the principal rupture. That helped me because there was no bile, and I was able to devote my attention purely to the spleen.

When the spleen is ruptured, being the graveyard of red cells, it possibly furnishes all the materials for an early and complete clotting. When hemoperitoneum and shock appear late it is evidence of a bursting of the

clot or the wall of the clot, whereas blood from the liver containing the taurocholic or glycocholic acids and their salts is inhibited from coagulating, and one is very liable to find a mass of dark, thick blood without any coagulating at all.

In one patient, the gunshot wound was not directly over the spleen, but perforated the chest wall, went through the edge or back surface of the transverse colon, and then struck the spleen. The piece of shrapnel—this was during the war—produced a splitting result. The missile went clear through the organ, and the radiating splits in the spleen opened up, leading to serious and in this case nearly fatal hemorrhage.

It is very difficult to expect a tamponade to cure that sort of rupture.

JOHN M. FOSTER (closing): I have very little, if anything, to say in closing. I am grateful to the gentlemen for their discussion. I might say that a possible reason we did not have some of the signs ordinarily present, is that the majority of these cases were observed in one of the city hospitals. The histories are frequently indifferent, and perhaps some of the signs and symptoms have been overlooked.

In delayed hemorrhage cases, it is most remarkable how a spleen can be found, part of it in the right half of the abdomen and yet have no hemorrhage occur for several days. Statistically, I believe the average length of delay in these cases is from four and seven days, which is a surprisingly long interval.

PRIMARY REPAIR OF SEVERED TENDONS

THE USE OF STAINLESS STEEL WIRE

STERLING BUNNELL, M.D.

SAN FRANCISCO, CALIFORNIA

OF the many tendons throughout the body, those which are most frequently severed are in the hand and wrist and in the foot and ankle. The commonest sites by far are in the hand and wrist, the most frequent of all being the flexors in the proximal segment of a finger.

The large tendons, such as Achilles, hamstrings, quadriceps, biceps and triceps, are not difficult to repair successfully, but those frequently severed and presenting a more difficult problem are about the hand and wrist and the foot and ankle where the tendons pass through narrow rigid tunnels. Here, after tendon repair, adhesions to sheaths too often limit or prevent movement. If loose movable tissues surround the repaired tendon, success is almost assured, but not so if the repair is in firm synovial lined fascial tunnels. Thus extensor tendons give the best results, then come flexors in the forearm and in the palm, and worst of all, and also the commonest, flexors in the proximal segment of a finger. Here the tunnel made by the annular ligament is firm, narrow and over an inch long. When the problem of repair here is solved, the repair of all other tendons is made possible.

PRIMARY TREATMENT OF THE WOUND

Before specifically discussing primary tendon repair let us first lay the foundation of first aid treatment of wounds in general.

The proper early surgical procedure determines the fate of the patient, in that if tendons, bones, and joints are injured and exposed the patient can, by the first treatment, be spared long illness from sloughing tendons, infected joints and osteomyelitis and will also be spared extensive permanent crippling. This can be done by operating early, debriding thoroughly and by saving all vulnerable tissues by covering them over.

1. *Time Factor.* All wounds are potentially infected. By debridement these germs can be excised. The golden time to operate, therefore, is soon after the accident and before the germs have had time to multiply. We can then, by debridement, convert a laceration into a clean surgical wound and thereafter reconstruct the nerves, ten-

dons, bones, etc., and cover over all vulnerable tissues. Also we can use local, block, brachial plexus or spinal anesthesias, which are dangerous in the presence of infection.

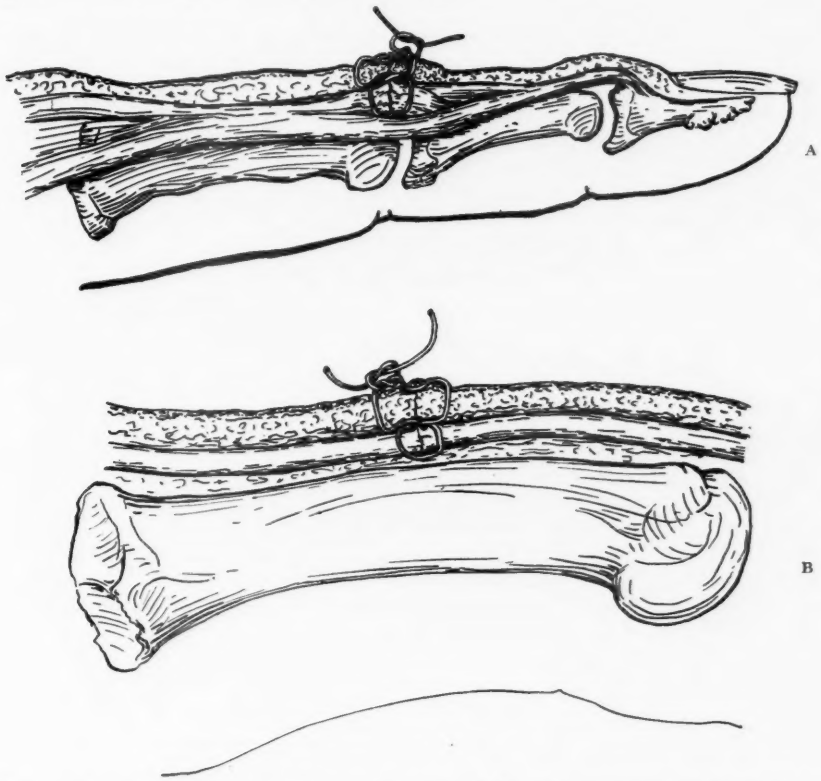


FIG. 1. A, primary suture of severed central slip of extensor tendon with simple figure of eight stainless steel wire relying more on splinting to prevent parting. B, similar method of primary suture of tendon on dorsum of hand.

Many authors place the limit of time for suturing tendons at from two to six hours following the accident. They base this on hospital statistics of operations done over many years and by multiple surgeons and do not stress the value of debridement and splinting. It is my conviction that, given a clean-cut laceration which has not been tampered with, one can, by thorough debridement, followed by postoperative immobilization, elevation and dry air dressing, suture tendons up to twenty-four hours after injury. Primary union can be obtained providing that a smear is free from cocci and excess of pus cells. Of course, it is preferable to suture tendons under twelve hours and the earlier the better, but if we observe all other factors we can in selected wounds succeed up to twenty-four hours.

Beyond twenty-four hours tendons should never be primarily sutured and even within twenty-fours hours only under the best of

conditions. Tendons should not be sutured even early, in the presence of extensive contusion, lowered vitality of tissues and ground in dirt. Contamination from out of doors is worse than that received indoors.

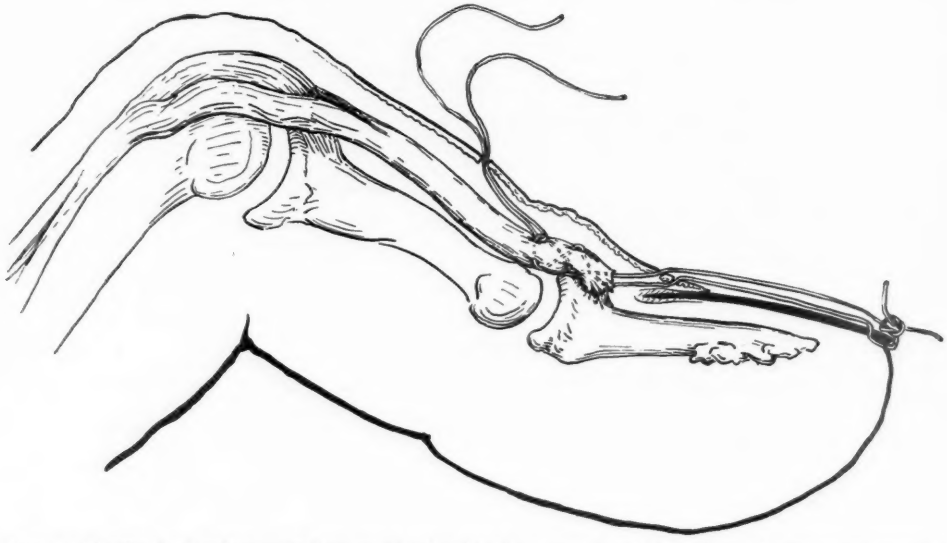


FIG. 2. Method of using stainless steel wire for late repair of insertion of extensor tenson, fastening the suture wire to the finger nail and later removing it by the pull out wire.

Tendons should not be sutured primarily unless hospital facilities are good and only by a surgeon trained in this particular field.

2. *Debridement.* The second important principle to observe in the primary suture of tendons is to do a careful and thorough debridement. Without this, tendons should not be sutured as the wound is destined to go through a stage of ridding itself of a layer of traumatized infected tissue by necrosis, sloughing and infection. Infection frequently follows such tendon suture and is often extremely severe. The following is the technique referred to by the term debridement.

Cover the wound with gauze and shave and cleanse the surrounding area with soap and water. With gauze still over the wound, wrap the limb in a towel and wind it bloodless from the fingers to above the elbow with a rubber Esmarch bandage. One and one-half inches above this apply the cuff of a blood pressure apparatus and pump to 300 mm. Hg., clamp the tubes and remove the Esmarch. An Esmarch tourniquet should never be used as it causes paralysis.

Paint the surrounding area with equal parts of tincture of iodine and alcohol. After giving local or block anesthesia (never adrenalin in digits) iodize the wound in all its depths.

Debride the wound, that is, convert it into a nontraumatized aseptic wound by excising its complete surface, sparing essential structures as nerves, vessels and tendons. With sharp, flat, curved

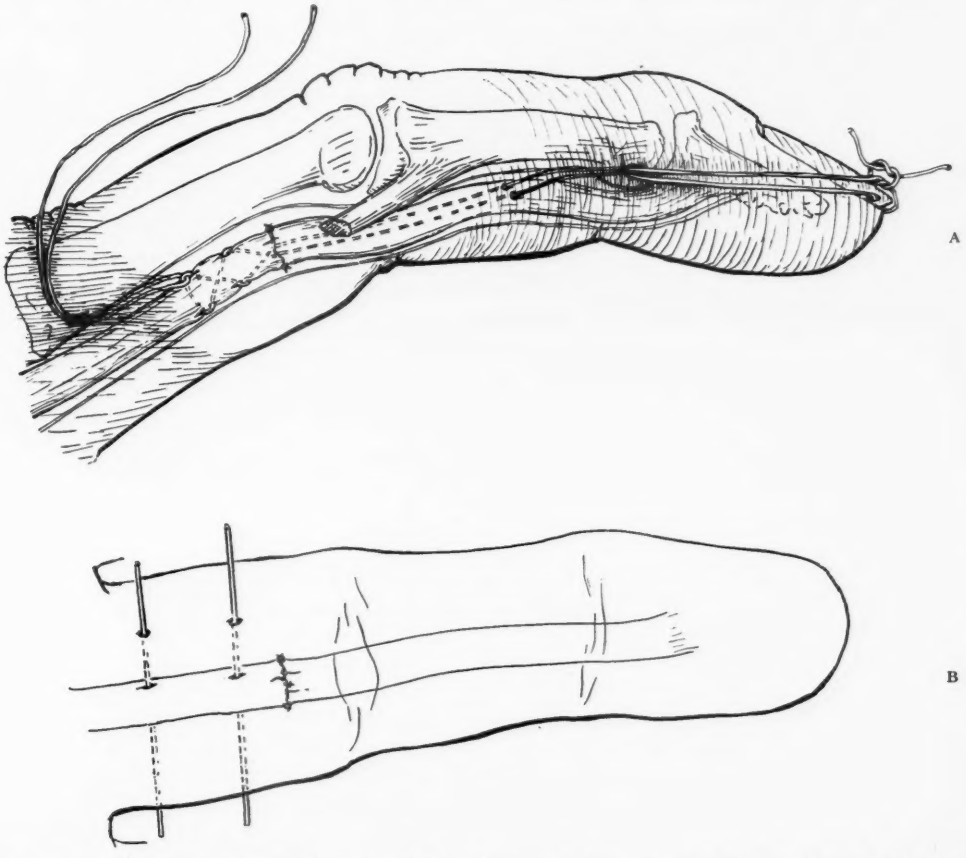


FIG. 3. A, primary suture of flexor profundus in proximal segment of finger. Use of stainless steel wire as a removable suture. Suture wire holds proximal tendon end distalward by passing through the distal tendon, then down the tendon sheath and out through the skin, being attached to the finger nail. The pull out wire is left in place ready to withdraw the suture wire in three weeks when it is clipped off at the skin. Only the profundus tendon is sutured. The sublimis is withdrawn. The annular ligament is slit laterally to allow circulation of the tendon ends during the stage of swelling. This stitch allows for some postoperative exercise. B, simpler method of joining a tendon, holding the proximal tendon end distalward by two or three steel pins. Tendon ends are approximated by a few tiny sutures of stainless steel wire No. 36 or finest silk size .0025. Method does not allow early movement. Tendon may later be freed.

double-pointed scissors excise first the skin edges and then systematically the whole surface of the wound 1 or 2 mm. deep or more if the tissue is too badly traumatized.

Chisel off infected bone ends thinly. Shave off infected ends of tendons and nerves, removing all the iodine stained tissue, so that there is throughout a surgically aseptic wound of viable tissue.

3. *Covering over Vulnerable Parts.* Tendons, nerves, joints and bones cannot live exposed to the outside world, and when infected cause sloughing, months of dressings and final crippling. In the

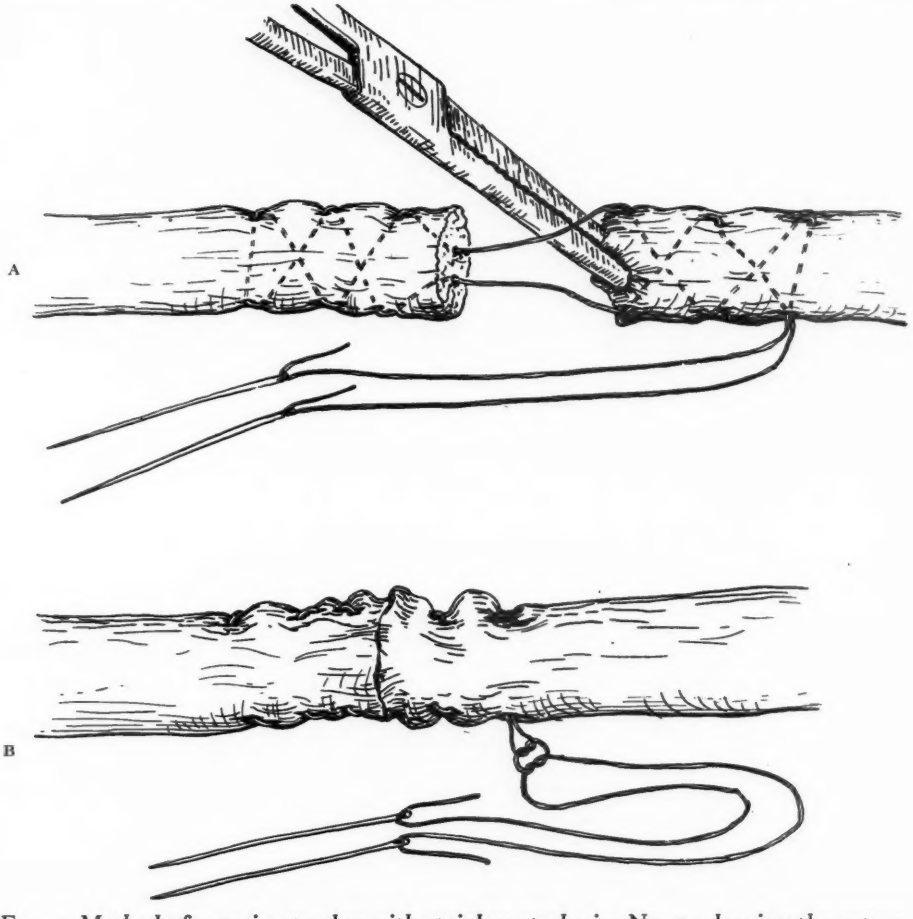


FIG. 4. Method of suturing tendon with stainless steel wire No. 34, leaving the suture permanently in place. A, placing the stitch. The tip grasped by hemostat is clipped off. Care must be used to avoid any kink. B, the tendon ends are bunched well together by sliding them over the smooth wires which are pulled alternately. This prevents later separation of the tendon ends. The wires are knotted together, allowing the knot to sink into the tendon.

golden time before germs have multiplied, all these structures should be spared by the method of covering them over by plastic swinging of skin flaps from the immediate neighborhood. The denuded areas from which the skin flaps are swung should be covered by immediate Thiersch skin graft. By this simple maneuver the saving from an economic standpoint is tremendous.

The tourniquet is then removed and hemorrhage checked by steady pressure for a few minutes and a minimum of fine ties. The

skin and dead spaces are closed, preferably by stainless steel wire No. 35. Buried stitches are omitted or reduced to a minimum. Drainage by slender rubber tubes is used only if seepage is from a large

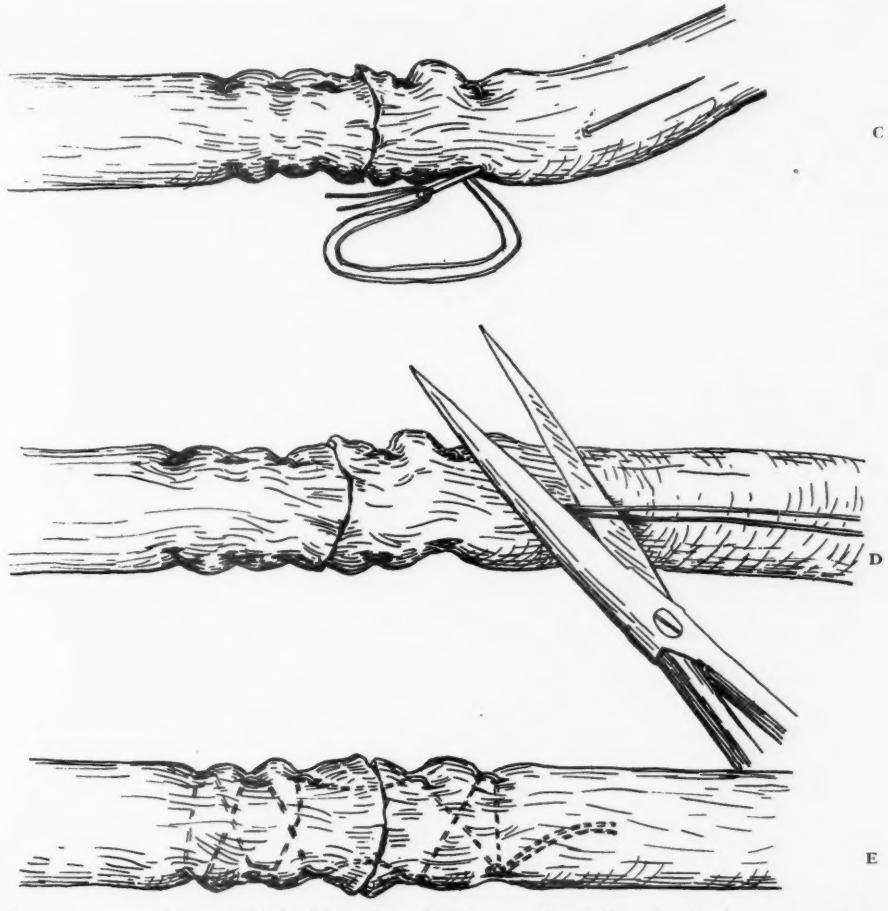


FIG. 4. C, D and E, method of burying the loose ends of the wire in the center of the tendon so that they will not scratch the sheath. This suture with No. 34 wire has tensile strength of 5 pounds which is enough for early protected movement.

area and even then, drains are removed the following day. The limb is immobilized in plaster of Paris. Mild gauze pressure is applied for a few hours or until next day to prevent hematoma. The wound is then allowed to dry uncovered, protected only by a wire cage and gauze or towel covering over that. Even dry gauze dressings become moist in twenty-four hours and encourage infection to enter along the stitches. Dryness prevents this. An injection of 1500 units of antitetanic serum should be given.

Primary suture of tendons should not be done except under these strict indications of time factor, condition of wound, hospital

facilities and special training of surgeon. If these are not available, the wound should be debrided and closed and vulnerable parts should be covered over. No attempt should be made to unite

FIG. 5. Result of primary suture of flexor tendon in proximal segment of a finger with a stainless steel wire removable suture as shown in Figure 3A.

tendons. They can better be repaired later, a month following healing per primam, or if infection has occurred not less than four months after all wounds have healed. A delay of six months is necessary if there has been infection of bone. Infected sutured tendons result in terrible infection that extends rampant up tendon sheaths and spreads through a limb, resulting in crippling or even death. A tendon should never be sutured after twenty-four hours and never in wounds that are traumatized or dirt ground and never without thorough debridement. One crumb of necrotic or infected tissue may cause infection. Skin should never be closed if soiled or devitalized tissue is in the depth or serious infection will follow. Old wounds excised after twenty-four hours should not be sutured closed. A limb should be immobilized continuously and without interruption until the danger of infection is over and should be kept

elevated to prevent edema and poor circulation. One should not seek primary closure if tissues are mangled or dirt ground.

NORMAL TENDON FORMATION

A tendon is enclosed in a thin, close, tight-fitting membrane called epitenon. Interlacing inwards from this between the bundles of tendon cells are connective tissue septa called endotenon. Where the tendon runs straight it is, instead of being enclosed in a tendon sheath, surrounded by paratenon tissue. This is a loose specialized sort of fat lightly attached to the tendon and also to the surrounding fascial tunnel. It is loose and gliding to allow ample excursion of the tendon through it. Where, however, a tendon rounds a corner, as opposite a joint, or around a bony prominence, a tendon sheath formation is present. Here the tendon is free, hung only by a loose sheet of blood vessel bearing mesotenon, or, as in the fingers, by narrow vinculae. The sheath at each end forms telescoping folds, called plicae, which allow for the to and fro motion of the tendon. In sheath formation when a tendon is severed the ends retract far. Their ends merely round over and are found unattached and free in the sheath. Severing in paratenon results in less retraction but rapid proliferation of the connective tissue in and about the tendon end so that a long flame-like projection reaches out and attaches to whatever tissues are there or to the opposite tendon end, if possible, in nature's effort to repair the damage.

HEALING AFTER SUTURE

The healing of tendons has frequently been described, this has been especially well done by Mason and Shearon. Soon after the tendon ends are sutured there is great proliferation of the connective tissue elements in and around the tendon—endo, epi and para—resulting in the rapid formation of a gelatinous fibroblastic splint between tendon ends well established in four days and quite advanced in two weeks, but without strength. Tendon cells are seen to proliferate in four days and in two weeks have bridged the gap. They furnish the strength so that in three weeks splints can be removed and in four weeks the danger of breaking is over. There is much swelling in the first two weeks. Thereafter, the connective tissue elements undergo a loosening process around the tendon to allow movement. Healing in paratenon formation is more active than within a sheath because of the surrounding vascularity.

Problem in Suturing a Tendon in a Sheath. When a tendon severed in sheath formation is primarily sutured, theoretically there

should be certain advantages, namely, the muscle can easily be drawn out, a synovial lined sheath will still be present and the gap between the tendon ends will not be filled with scar tissue as in late repair. It will be found, however, that the tendon juncture will grow fast to the sheath as there is rapid exuberant growth of the connective tissue elements in an effort to establish attachment to something.

A great indirect cause of attachment is that the tendon ends, where sutured together first, go through a stage of swelling. This is caused by the natural healing, the double trauma of the laceration and the surgery, and also the reaction produced by the suture material itself. Consequent ischemia from swelling in an unyielding sheath results in necrosis which is of necessity followed by cicatricial adhesion. A common example of this from excessive trauma is seen in the usual binding of a tendon by adhesions opposite a fractured phalanx.

A tendon will, however, tolerate a degree of surgery and still retain its function. Thus we can open a tendon sheath along the side of a finger, thoroughly exposing and even handling the tendon. The tendon sheath and finger can then be closed and good function will result. It is evident, therefore, that to solve the problem of repair in a tendon in its sheath we must develop a method of minimal trauma to lessen tissue reaction. The narrow caliber of the firm tunnel of the tendon sheath at the place of suture is a factor in causing adhesions. Therefore, such a fascial tunnel should be slit laterally to allow the tunnel to expand to a large enough caliber to accommodate for the necessary swelling of tendon repair.

A primary tendon repair provokes so much cicatrix that all structures should be handled with minimal trauma. The ends are joined with the simplest stitch and with suture material which is least irritating. In late tendon repairs the stitch may be more elaborately spliced into a length of tendon so it will withstand the strain of early exercise, but in primary repairs the suture should be the simplest that will hold the tendon ends lightly together in good approximation. To prevent breaking we should rely more on splinting than on suture material.

The material of suture is important. Chromic catgut is prone to infection, specific sensitization and cicatricial reaction. O'Shea, in reviewing 870 tendon sutures, reported infection with it six times as frequently as with silk. Strong braided fine untreated silk No. 2 has been the usual suture of choice. However, this material is a foreign body which creates tissue reaction resulting in adhesions which

are our main cause of failure in suturing a tendon in a sheath. We should therefore select a suture material that gives the least tissue reaction.

From the study of Venable and Stook, vitallium and stainless steel were found to be the least irritating to tissues as they are non-electrolytic. There is available excellent very thin flexible wire of stainless steel. For three years I have used this continually for skin suture and am enthusiastic over its freedom from irritation in the skin where we can clearly see it. We often cover it with a plaster cast for months without concern, for it does not cause irritation. Babcock has popularized its use in infected wounds and has shown that granulation tissue will grow over and bury it. Of all suture materials stainless steel causes the least reaction and it is therefore logical to use it for tendon suture where adhesion-forming irritation is especially to be avoided. If placed centrally in a tendon with the free ends buried in the center of the tendon so that they will not scratch, the wire may be left in with confidence of better tissue toleration than in the case of silk. For the mechanical effects more time is needed.

A simple stitch, with a needle at each end of the wire No. 34, first penetrates the tendon transversely. The needles, after crossing around a few tendon fibers, then pass through the tendon diagonally from opposite sides and again penetrate diagonally to emerge from the center of the tendon ends. The two wire ends are then pulled to remove all slack, the wire sinking out of sight into the tendon. With the tip of the opposite tendon end held taut in forceps (and later clipped off) the two wires are similarly placed, starting at the tip and emerging from the same point farther down the tendon, having passed diagonally through twice and one of them also transversely. The second tendon end is then slid down these smooth wires and tied to the other, the knot burying itself in the tendon remote from the suture line. The two wires are then threaded through the depth of the tendon and cut off. Such a stitch withstands 5 pounds. Care should be used to avoid kinks as these cause the wire to break. The tendon ends have been bunched together so they will not separate. Approximation can be made exact if necessary by a tiny stitch of .0025 silk or No. 36 wire.

There is never trouble making tendon ends unite, but often trouble from outside adhesions. Therefore, it is better to have the stitches buried than irritating at the sides of the tendon where we do not want adhesions. A central core suture is not objectionable as all necrosis from the grasp of the stitch is eventually displaced

by tendon tissue. This necrosis is better central than peripheral, since the latter would cause adhesions. Nowhere is the full thickness of the tendon strangled of blood supply and the ends of the tendons themselves are free from suture for good repair.

We have also been using the wire suture removable from the outside. This is not difficult considering that it is only the proximal end of the tendon that pulls, the distal tendon end being merely passive. The stitch is placed in the proximal end only and the two wires emerging from the tendon end are passed on up through the center of the opposite or distal tendon end and out through the skin to a firm attachment in the finger nail or to an adhesive plaster applied broadly to the skin. Tiny sutures of No. 36 hairlike wire accurately approximate the tendon ends, but the main wire stitch holds the proximal tendon end distalwards so the tendon ends cannot pull apart.

In order to remove the wire three weeks later, a second wire is threaded through the proximal loop of the suture wire and its two ends threaded on a straight needle are passed proximalwards up the tendon sheath a short distance and then out through the skin and left there. This is the pull out wire. When in three weeks the ends of the suture wire are cut off close under the skin where they emerge, the pull out wire easily withdraws the suture wire right out of the tendon and to the outside as it pulls it by its proximal loop. If there is resistance, a light rubber band left on will withdraw the stitch without danger of breaking. This arrangement allows for moderate excursion of the tendon in its sheath during healing in order to prevent adhesions to the sheath.

Postoperatively, adhesions are guarded against by exercise. Flexing the joints distal to the tendon suture pushes the tendon proximalward in the sheath. Thus the flexor tendon is pushed an inch into the palm by passively flexing the finger. As both the suture wire and pull out wire have been passed for some distance through the sheath before emerging through the skin, the wires will not hinder this motion nor the natural pulling motion of the tendon. Such a stitch is useful in the hands and feet and in joining tendons to their insertion, especially in suturing within a sheath.

A simpler method is to transfix the proximal portion of the severed tendon through and through the finger or limb with two or three stainless steel pins. Two pins in a finger will prevent the proximal tendon end, up to 5 pounds, from pulling away from the distal end. A tiny approximation stitch of No. 36 wire should also

be used. This method results in some adhesions to the sheath as it does not allow motion. Later the adhesions may be freed.

With the above methods reliance should not be placed on the strength of suture, but instead on immobilizing the joints in flexion by plaster of Paris to leave the involved muscle in complete relaxation. In the case of a flexor tendon in the hand or wrist, only the wrist should be flexed in this way and not the fingers. The muscle will then not be able to move forcefully enough on the tendon to separate the sutured ends. However, there is enough weak motion to stimulate growth and lessen adhesions while physiologic union is occurring.

Extensor tendons in hand and forearm are successfully united by the simplest figure-of-eight stitch of stainless steel wire, passing through the skin as a mattress suture and forming the deeper loop of the figure-of-eight through the tendon ends to hold them together. Both wrist and digits are then held in almost full dorsiflexion for three weeks, when the stitch is removed; another week of less dorsiflexion is then allowed.

If only the flexor sublimis of a finger is severed, it is best to let it alone. Suturing it will cause it to adhere to the profundus. If both sublimis and profundus tendons are severed, the sublimis should be allowed to retract and the profoundus alone be sutured. If both are sutured they will become fast to each other and so will act on only the middle but not the distal joint of the finger.

CONCLUSIONS

Primary repair of tendons should not be done except under strict indications covering the nature of the wound and adequate facilities of both hospital and surgeon. Operation must be prompt, debridement thorough and all vulnerable parts should be closed over. Repairing within a sheath is the most difficult. Trauma should be minimal and the tendon stitch simple and of non-irritating material, preferably stainless steel wire. This may be left in the tendon or be placed in such a way that the wire is removable.

DISCUSSION

HOMER D. DUDLEY (Seattle): It has been my privilege on a number of occasions to visit Dr. Bunnell and see his work. I have always been fascinated by everything he does, and have about concluded that he is as much a magician as a surgeon. I no sooner learn one of his intricate methods than he springs a new one on me. The last time I saw him he told me about

his use of silver wire. I have had occasion to use wire three times since then. The results are yet to be seen.

The problem of suturing severed tendons of the hand, especially that portion in rigid tunnels, has not been solved satisfactorily. Many forms of treatment and definite technique have been recommended to meet this condition. There is no difference of opinion as to the exact fundamental requirements for success in suturing severed tendons. Obviously, the type of suture material and its application surgically does not solve the problem as a whole. Under ideal conditions, utilizing all the fundamental principles, there is still an element of failure. The end result, therefore, is modified by one or another of those factors over which the surgeon frequently has no control. The type and location of the injury, element of time, age of the patient, conditions incident to primary and surgical trauma, infection, preparation of the wound, together with the type of suture material used and technique employed are only some of the factors. There still remain those anatomic and physiologic conditions peculiar to tendons that predispose to formation of adhesions.

A study of the physiology and anatomy of tendons is helpful in understanding the necessity for atraumatic technique, also a knowledge of tendon tension and its application in primary suture and postoperative care.

Because of the tendency of severed tendon fibers to rapidly proliferate and attach themselves to some neighboring structure, a most exacting technique is demanded. Various measures and agents to prevent the formation of adhesions have been employed. These may be divided into two groups: that method whereby some tissue has been employed to surround the site of tendon injury such as fat, fascia, blood vessels, various forms of animal membrane, and so forth; and the second, in which some non-resorbable foreign material has been used to reconstruct the tendon sheath such as celloidin tubes, modeled cartilage, magnesium, and stainless steel rods. All of these have offered some improvement. The former are practical chiefly in the primary repair of tendons, not in fibrous spaces, and the latter as secondary or reconstructive measures.

All are agreed that regardless of these measures, certain fundamental principles are essential for a minimum of success, as atraumatic technique, avoidance of infection, complete hemostasis, accurate apposition of severed tendon ends, the use of non-irritating antiseptics and suture material, appropriate dressings, splinting and postoperative care. When one realizes the importance of employing all the fundamental requirements for success in primary repair of severed tendons, it is difficult to evaluate any one measure as being more important than another. Suture material is only one of these and best of all is the one least irritating. Here stainless steel wire may prove most valuable.

Dr. Bunnell has offered an ingenious method which may improve one or more of these requirements and likely to better functional end results. I would like to ask Dr. Bunnell if he would consider it applicable to use

removable wire sutures to hold severed tendon ends in their normal relationship, when the time for ideal primary repair had passed and in the period when infection is likely to occur. One might fix the proximal end of the tendon and bring the wire out at a distant point, fix it in place and close the skin. If the wound did not become infected, the wire would hold until the appropriate time for secondary repair. If infection occurred and it seemed desirable, the wire suture could be removed easily.

LAURIE H. MCKIM (Montreal): As Dr. Dudley has just stated, we no sooner get accustomed to a very careful technique of Dr. Bunnell's than he brings out something that sounds even better. We all know the work he has done, and I think the majority of us believe that whatever suture material Dr. Bunnell happens to use, he will probably have a little better result with it than we will. I am sure all who have taken notice of his previous work, his direction to the great need for careful technique and the avoidance of trauma, believe that this new departure, the use of steel wire as a suture material for tendons, may prove valuable.

The introduction of steel wire in tendon work brings up the whole question of the pathology of foreign body reaction. We may have to revise some of the opinions we have held. We know that foreign body reaction is probably of three kinds—chemical, allergic, and electrochemical. There are probably others, but we have accustomed ourselves to grouping all together as simple "foreign body reaction." It would seem that Dr. Bunnell's stainless steel wire has possibly overcome the majority of the factors concerned in this reaction.

My own practice in the past ten years has been, unless the case is seen within two or three hours, not to suture any tendons on the dorsum of the hand. I place the hand in a plaster of Paris "cock-up" splint to the ends of the fingers. I leave the cast on for six weeks. I have yet to get a failure of union, and I have yet to get other than absolutely perfect function in any case.

I should like to ask Dr. Bunnell whether he considers that the use of stainless steel wire would be equally applicable in the insertion of tendon grafts.

STERLING BUNNELL (closing): I wish to thank the discussers.

The problem of primarily suturing a tendon in a sheath is not yet solved. I do not claim a solution, but am striving toward some method that will improve our results because they are unsatisfactory the world over. I hope by this paper merely to direct the trend of thought along a line that will give better results.

The use of stainless steel wire is, of course, not the only factor. It is just one and there are many others which are essential for success.

I think Dr. Dudley's suggestion is excellent in that in some instances where elaborate suturing is inadvisable one can merely place a figure-of-eight stitch or do something simple, temporarily to hold the two tendon ends together until secondary repair is done, just as we often do in primary

nerve repair. This will keep the muscle from contracting. Usually after two months tendon ends can be drawn together but not after three months. An objection is that two operations leave more adhesions than one.

It is very important in placing these wire stitches never to kink the wire, and that is up to an assistant to hold the slack of the suture, because any kink that forms in the wire will make it break.

Dr. McKim mentioned tendon grafts. The wire acts in free grafts just as well as in any tendon. There is no essential difference.

TRAUMATIC LESIONS OF THE NERVES OF THE WRIST AND HAND

TORR WAGNER HARMER, M.D.

Instructor in Anatomy, Harvard Medical School; Assistant Surgeon Massachusetts General Hospital

BOSTON, MASSACHUSETTS

A MAIMED hand is a calamity. If it befalls an individual of financial independence, he is subjected to the embarrassment of the unsightliness of the member and is deprived of

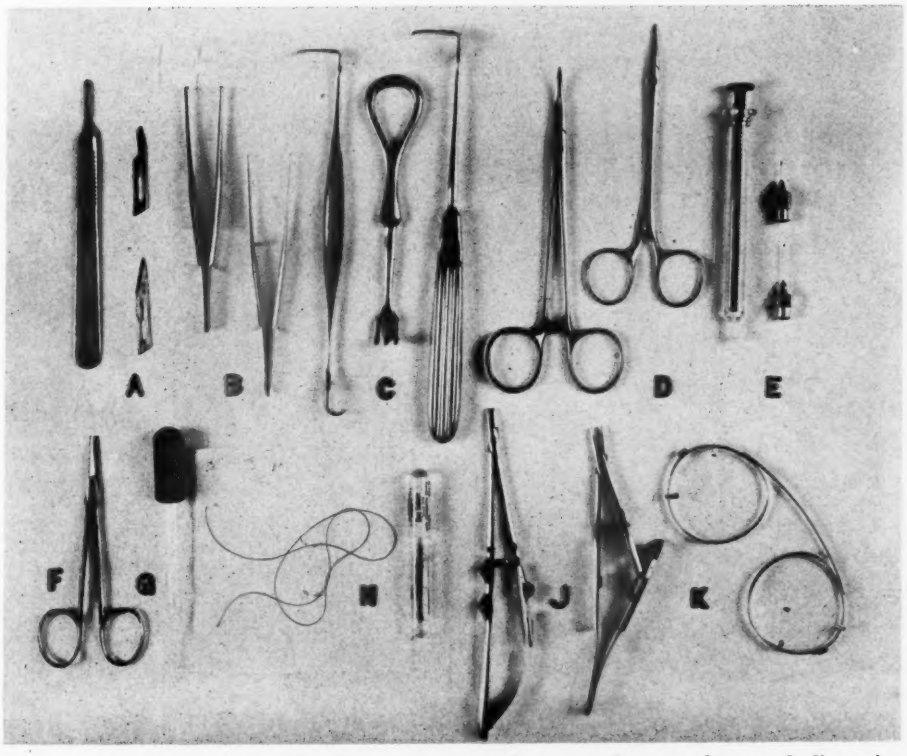


FIG. 1. Armamentarium. Fine instruments used to supplement the usual dissecting kit. A, knife handle and blades. B, fine toothed forceps. C, retractors. D, hemostats. E, syringe and needles for nerve injection. F, scissors. G, dropper for neurorrhaphy. H, fine needles carrying 4-0 and 6-0 silk. J, needle holders. K, magnifying lenses which may be clasped over spectacles.

participation in certain activities which contribute to his happiness. If it befalls an individual who must rely entirely upon his hands for his livelihood, the physical affliction may so seriously alter his economic status that he and his dependents may be reduced to a

FIG. 2A.

FIG. 2B.

FIG. 2. Median neurorrhaphy and tenorrhaphy at wrist. Girl, age 3, received severe wound with glass across anterior surface of wrist, dividing all structures except the ulnar nerve and flexor carpi ulnaris tendon. Repair several hours after injury. Photographs (A, B and C) taken eleven months later show perfect apposition and flexion and extension of fingers. The case is interesting on account of the small size of the parts and because of the use of squeaking rubber toys to secure active movements. (From Harmer, in *Boston M. & S. J.*, 194: 739, 1926.)

wretched existence. Disabilities may be due to several causes. It is my purpose to consider those disabilities consequent to trauma of the nerves of the wrist and hand. The prevention of disability

FIG. 2C. For descriptive legend see opposite page.

depends upon the immediate recognition of the nature and extent of the injury and upon immediate repair. When the disability is established, amelioration depends upon the recognition of the underlying pathology and upon reconstruction undertaken sufficiently early to insure a reasonable expectancy of nerve regeneration.

Anatomy. The nerves which may be injured are the median nerve with its branches, the ulnar nerve with its branches, and the distal branches of the radial cutaneous nerve. The *median nerve* at the wrist lies between the palmaris longus (when present) and the flexor carpi radialis but at a somewhat deeper level. It passes beneath the transverse carpal ligament (volar retinaculum) and approximately at the distal margin of the ligament breaks up into branches like the crown of a tree. The lateral group consists of three branches. The first is the so-called motor nerve to the thumb, which crosses the radial bursa and supplies the superficial muscles of the thenar eminence (abductor pollicis, apponens pollicis and the superficial head of the flexor brevis pollicis). The other branches of this group are distributed to the two sides of the thumb and the radial side of the index finger. From the latter nerve arises the twig to the first

lumbrical muscle. The medial division consists of two branches which run distally towards the clefts between the index and middle and the middle and ring fingers. They separate into digital nerves for

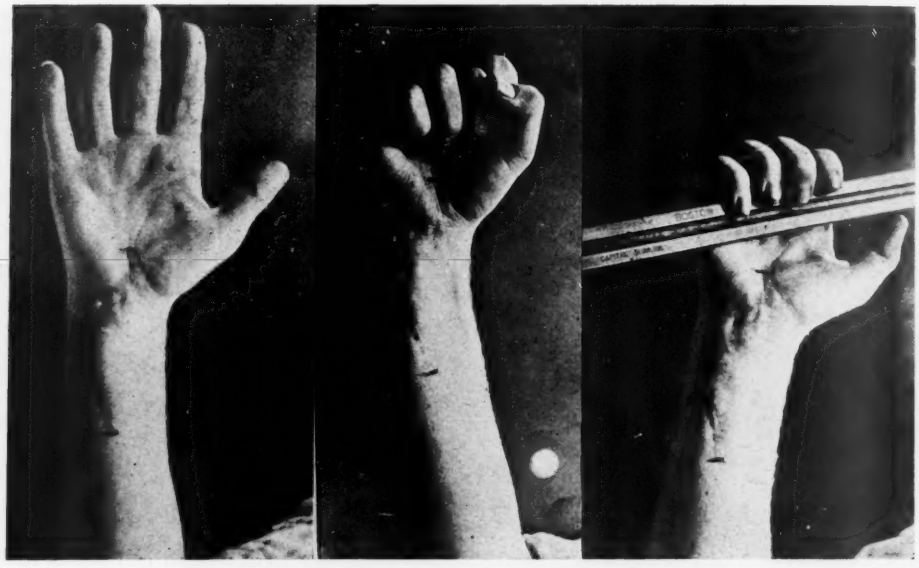


FIG. 3. Neurorrhaphy (median and ulnar) and tenorrhaphy (flexor carpi ulnaris, all of profundus, two of sublimis and palmaris longus) performed twenty-four hours after injury (thrusting arm through pane of glass). Pictures taken five months after operation show extent of wound, development of thenar and hypothenar eminences, action of intrinsic muscles supplied by both nerves, and flexion and extension of fingers. Note rapidity of regeneration in this high school athlete. (From Harmer, in *S. Clin. North America*, 1: 809, 1921.)

the adjacent sides of these digits. From one is given off a twig to the second lumbrical. Although these palmar digital branches of the median nerve pass deep to the superficial volar arch, they ultimately come to lie to the volar side of the digital arteries in the fingers. It is to be remembered that these nerves also supply the distal portions of the dorsal aspect of the thumb to the base of the nail, of the index finger to the distal joint, and of the middle and ring fingers to the middle joints.

The *ulnar nerve* at the wrist courses between the tendon of the flexor carpi ulnaris medially and the ulnar vessels laterally. It then passes in a special compartment superficial to the carpal ligament, skirting the radial margin of the pisiform. Towards the distal margin of the ligament it divides into its superficial and deep branches. The superficial branch passes beneath the palmaris brevis muscle, which it supplies, and then splits into a medial division which innervates the medial margin of the hand and little finger, and a lateral

division which, coursing on the hypothenar muscles, splits to supply the contiguous margins of the ring and little fingers. The deep branch of the ulnar nerve with the deep branch of the artery sinks into the interval between the abductor and flexor brevis minimi digiti muscles, supplying these and the apponens minimi digiti. It then passes laterally on "bed-rock" beneath the flexor tendons of the fingers paralleling the deep palmar arch. By this route it reaches the deep muscles of the thenar eminence (the adductor obliquus and transversus pollicis and the deep head of the flexor brevis pollicis). On the way across the root of the palm it sends two branches to each interosseous space. These branches innervate the three palmar and four dorsal interossei and the two medial lumbricals. It is to be remembered that there exists an anastomosis between the superficial branches of the ulnar nerve and the median nerve at the root of the palm and another between the deep branch of the ulnar nerve and the median nerve at the base of the thumb. The frequent double innervation of the third lumbrical muscle should also be borne in mind.

There remain to be described the cutaneous nerves of the palm and of the dorsal aspects of the hand and digits. The palmar cutaneous branches of the ulnar and median nerves arise at or above the wrist, pass superficial to the transverse carpal ligament and are distributed to areas of the palm, generally speaking, medial and lateral to the long axis of the fourth metacarpal. The skin over the thenar eminence is, however, supplied by a distal continuation of the lateral cutaneous nerve of the forearm and by branches from the superficial ramus of the radial nerve.

The large sensory branch of the radial nerve gains the dorsal aspect of the lower forearm by passing beneath the tendon of the brachioradialis. Its four branches are distributed as follows: the radial margin of the hand and thumb, the medial margin of the thumb, the lateral marg n of the index finger, and the adjacent sides of the index and middle fingers. It should be remembered that there is another twig which joins a branch of the dorsal cutaneous nerve of the ulnar to supply the contiguous margins of the middle and ring fingers. It should also be remembered that these digital branches extend on the thumb to the base of the nail, on the index finger to the distal joint, and on the middle and ring fingers only to the middle joints. The posterior aspect of the hand and the medial digits are supplied through the dorsal cutaneous branch of the ulnar nerve. This nerve arises from the parent nerve about 2 inches proximal to the ulnar styloid. It then winds about the medial margin

FIG. 4A.

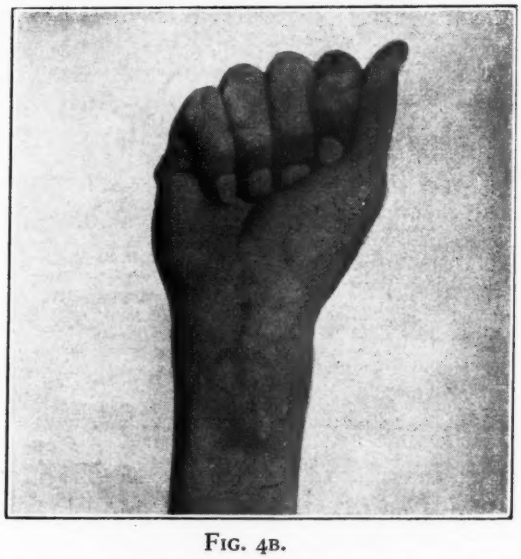


FIG. 4B.

FIG. 4. Neurorrhaphy (median and ulnar) and tenorrhaphy (all flexors) at wrist performed several hours after injury (thrusting arm through a pane of glass). Pictures taken nineteen months after operation show development of thenar and hypothenar eminences, action of intrinsic muscles supplied by both nerves, and flexion and extension of fingers. (From Harmer, in *Boston M. & S. J.*, 194: 739, 1926.)

of the hand a thumb's breadth distal to this process and divides into three branches. One of these innervates the medial margin of the hand and little finger, another continues on the dorsum to supply

FIG. 4C. For descriptive legend see opposite page.

the contiguous margins of the little and ring fingers, and the third continues distally to anastomose with a branch of the radial to supply the contiguous margins of the ring and middle fingers (as noted above).

Preoperative Examination. A careful examination should be made in all cases to gain an intelligent understanding of the damage before anesthesia is started. Since a nerve injury is rarely an isolated lesion but is usually accompanied by damage to other structures, the examination must be of the entire hand and wrist. With practice and gentleness this can be accomplished quickly and with very little discomfort to the patient. The repair of a lacerated wound, even an extensive laceration on the volar aspect of the wrist, should not be an exploratory operation.[3]

The situation and extent of the wound are noted and it is then covered with sterile gauze. The functions of the parts are tested. The surgeon executes with his own hand the movements which he wishes the patient to attempt. Beginning with the thumb, flexion and extension of each phalanx of each digit are tested. To this end it is helpful to support the joint proximal to the phalanx which is being tested. Except for the extension of the middle and terminal phalanges of the fingers, these are gross movements. The muscle bellies of these tendons are innervated in the forearm. To determine the

integrity of the ulnar and median nerves at the wrist, the intrinsic muscles of the hand must be tested. In case of the ulnar nerve these tests concern the ability to adduct and abduct the fingers and to

A B

FIG. 5. A and B, neurorrhaphy (median at base of palm) and tenorrhaphy (flexor carpi radialis, flexor sublimis and profundus of index finger, and palmaris longus) in palm and at wrist, performed two hours after injury (from gouges of a wood-fluting machine revolving 6000 times a minute). The soft parts were widely extruded through several more or less parallel undulating deep wounds, including lacerated muscles of the thenar eminence. Pictures taken five and one-half months after operation. Show extent of lacerated wounds, active apposition of the thumb and range of active motion of middle and terminal phalanges of index finger.

adduct the thumb, the ability to flex the fingers as rods at the metacarpophalangeal joints, and the ability to extend the middle and distal phalanges of the middle, ring, and little fingers, especially the ring and little. In case of the median nerve the functional tests concern the ability to appose the thumb to the tips of the fingers, to abduct (not extend) the thumb, and to extend the middle and terminal phalanges of the middle and index fingers, especially the index. Although tests for cutaneous sensation may be of value in estimating the repair problem in lesser injuries and in reconstruction work on the hand, the writer believes that the mental attitude

of the patient often renders them unreliable in extensive acute injuries. It is true that patients will at times volunteer the information that certain parts feel "numb" or "dead" and operative find-

FIG. 5C. Superimposed photograph, showing action of first lumbrical through median nerve. Note: full flexion of the terminal and middle phalanges of the index finger is prevented by scar tissue at the root of the palm and wrist. Will probably require correction by subsequent operation. Amputation of little finger from previous accident.

ings will substantiate the accuracy of their observations. In cases of injury to the rami of the radial cutaneous or of the ulnar dorsal cutaneous nerves, sensory tests, of course, are indispensable.

The necessity for thorough preoperative examination is well illustrated in *multiple wounds.*[4] Wounds which seem trivial may be serious. Apparently insignificant wounds of the wrist may sever the median or ulnar nerves without injury to contiguous tendons. Unless special tests for these nerves have been made, their injury will be overlooked when operation for other wounds is undertaken. Subsequent neurorrhaphy will be necessary. It is needless to state that immediate repair of a nerve is not only much less difficult but also more likely to succeed.

The integrity of circulation may be determined by noting the radial and ulnar pulses at the wrist, the color and warmth of the hand, and the capillary blush in the nail-beds.

The appearance of the hand following *old injuries* of the median and ulnar nerves at the wrist is so characteristic that the diagnosis is at once apparent. In ulnar palsy the ring and little fingers are hyperextended at their metacarpophalangeal joints and flexed at their middle and distal joints. The hypothenar, deep thenar, and

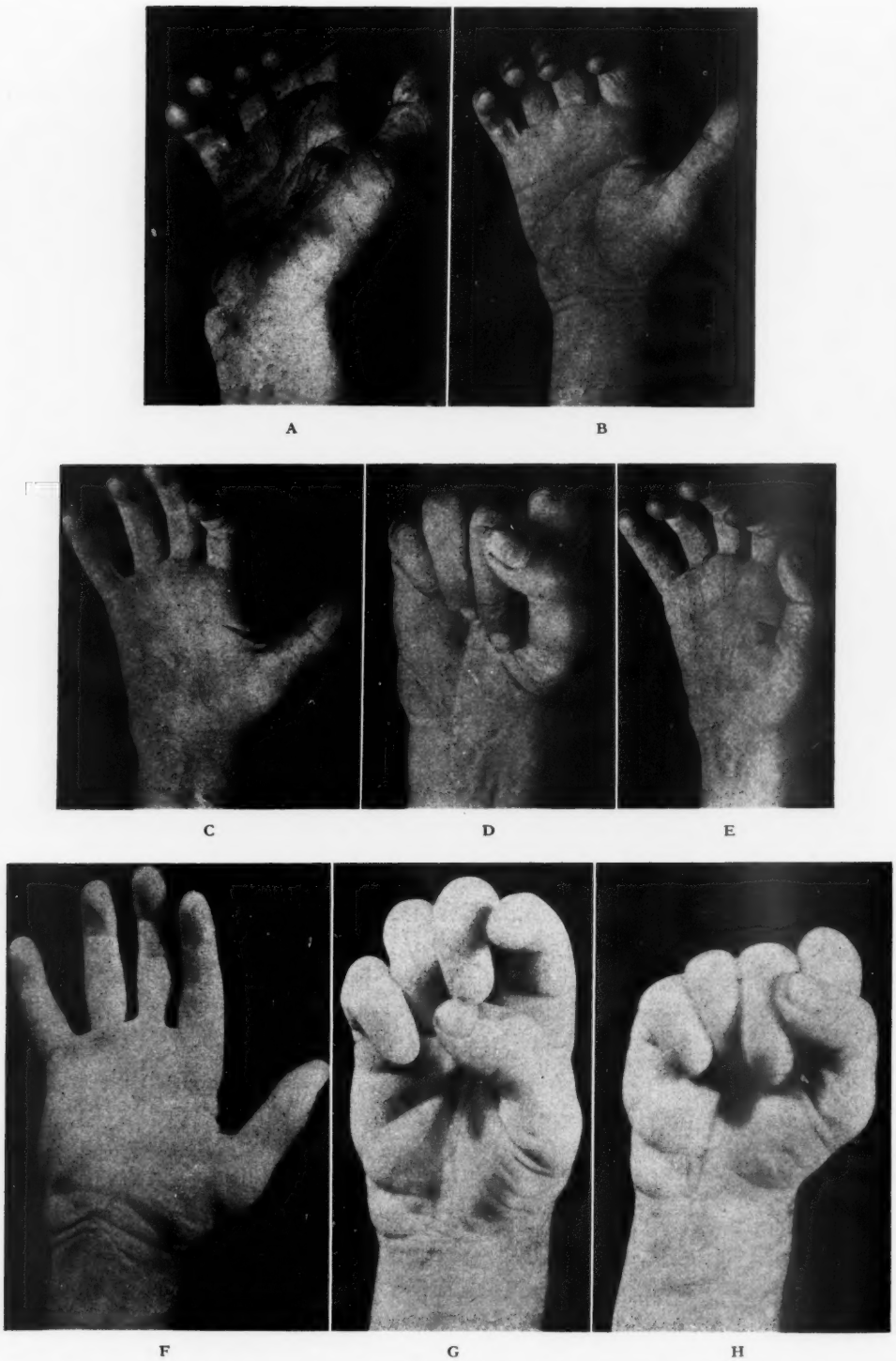
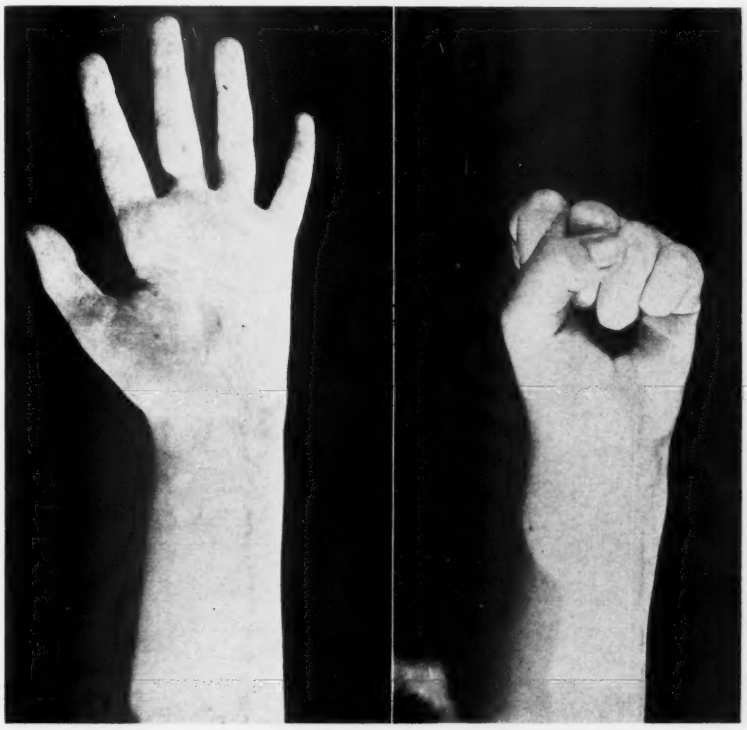


FIG. 6. Late median and ulnar neurorrhaphy and tenorrhaphy at wrist. An immediate repair had been attempted elsewhere eight months previously. A and B, ability to flex and extend fingers and thumb, September 19, 1928. Note atrophy of thenar and hypothenar eminences. Operation, September 21, 1928, showed both ends of median nerve sutured to tendons, ulnar nerve unsutured and other tendon ends matted and bridged by scar. C, D and E, ability to flex and extend fingers and thumb in May 1929. F, G and H, September 10, 1938, showing flexion and extension and ability to appose and adduct thumb. Note development of eminences.

interosseous muscles are conspicuously atrophied. In median palsy the thumb is held in a plane with the palm, producing the so-called simian or ape hand. The superficial thenar muscles are obviously



A B

FIG. 7. Girl, aged 9. Late ulnar neurorrhaphy at wrist. Seen seven months after lacerated wound of wrist. Immediate operation and another two months later had been done elsewhere. Pictures taken nine months after third operation. Show extent of wound necessary to effect suture, and action of intrinsic muscles supplied by ulnar nerve.

atrophied. When both the ulnar and median nerves have been injured, the hand presents a combination of these characteristic changes and the entire thenar eminence is wasted.

Despite such obvious features an examination of the whole hand, as described under acute injuries, must be made to determine the integrity of other structures. Were any tendons coincidently severed? Have any joints become subsequently impaired? Tests for muscle function must be carefully observed because rebound and supplementary motility may simulate movements which may be expected to be impossible in a particular nerve palsy.[7] For example, relaxation following strained hyperextension at the metacarpophalangeal joints may produce rebound flexion at these joints.

Again, in a median nerve palsy, apposition of the thumb may be simulated by the combined action of the adductor and deep head of the flexor brevis pollicis muscles. Testing regional sensibility by

FIG. 7C. Development of hypothenar eminence and action of interossei.

pin-prick alone will lead to false deductions regarding the degree of involvement of a sensory nerve. Both epicritic (light touch, slight changes of heat and cold, compass points) and protopathic (pin-prick, extremes of temperature) tests should be employed. It is to be remembered that after the division of a sensory nerve the area of total anesthesia is less than the area of anatomic distribution of the nerve.[5] In the examination of old injuries the presence of neuromata may be revealed by their localized hypersensitiveness. Regional paresthesia may suggest scar constriction of a nerve, for example, the organization of a subfascial hematoma as a sequel to a crush of the hand by rollers.

Armamentarium. The surgery of nerves is delicate work. Appropriate instruments in good condition are indispensable. The accompanying illustration (Fig. 1) shows a few special instruments which are used to supplement the usual dissecting kit. Most of the work is done by sharp dissection. This causes less trauma than the crushing of scissors. For the same reason no smooth forceps are employed. Curved needles swaged with fine silk facilitate nerve suture and minimize trauma. The magnifying lenses can be clasped

over spectacles and are found serviceable by the author for inspecting the ends of nerves which are being transected in preparation for neurorrhaphy following old injury.

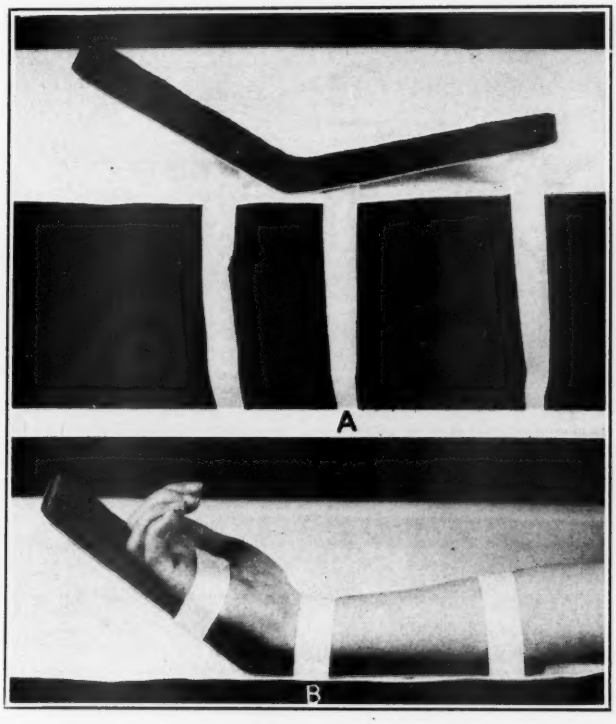


FIG. 8. Wrist splint of felt-covered aluminum used following repair of nerves and flexor tendons at wrist, A, the splint has been gently angulated to receive the flexed wrist. B, splint in use. Although the fingers can be actively moved, tension on the sutured nerves is prevented. The support of the fifth and fourth metacarpophalangeal joints prevents undue stretching of hypothenar muscles in case of ulnar neurorrhaphy. The addition of the thumb cot (Fig. 10) similarly protects the thenar muscles in case of ulnar or median neurorrhaphy. The splint does not fit the subject, as the forearm portion is too short and the hand portion too long. (From Harmer, in *New England J. Med.*, 214: 613, 1936.)

Anesthesia. In most cases general anesthesia is necessary. The author has had no experience with novocaine block at the wrist or at proximal levels.

Preoperative Preparation. The preparation for immediate operation is very important. A hasty or rough preparation may ruin a pretty operation. In cases in which tendons are coincidently

severed the part is held during this procedure in a position which will prevent their further retraction. In the preparation of bad lacerations or crushes a very thorough but gentle cleansing with

A B

FIG. 9. Thumb cot of cotton suede to relax the thenar muscles. Used early in conjunction with aluminum wrist splint (Fig. 10) for neurorrhaphy and tenorrhaphy at wrist and later in those cases in which only the median nerve has been sutured (see text). Note double lacing from tip carried between fourth and fifth fingers to back of wrist, looped, carried through hem at base and tied about wrist.

soap and water is followed by prolonged douching with several quarts of sterile salt solution and completed by a douching with ether. During the process frayed tissues which are floated by the douche are snipped off and damaged tissues debrided. Thirty minutes devoted to cleansing of an extensive laceration in this manner are profitably spent. "Patience is a virtue." *Impatience to operate is too common a failing.*[4]

Gloves, instruments, and under-sheet are discarded. The *skin* is painted with half-strength iodine or one of the acetone-alcohol mercurials, and sterile drapes are placed. The hand is elevated several inches on a folded sheet or towels. For reconstruction work the hand and forearm receive twice daily preparations with soap, water, ether, and alcohol followed by a sterile dressing, for one or two days before operation. Shaving is done only at the last preparation.

The indications for antitetanic serum (or gas bacillus serum) and the technique of preliminary intradermal injection for testing sensitivity are the same as for wounds elsewhere in the body.

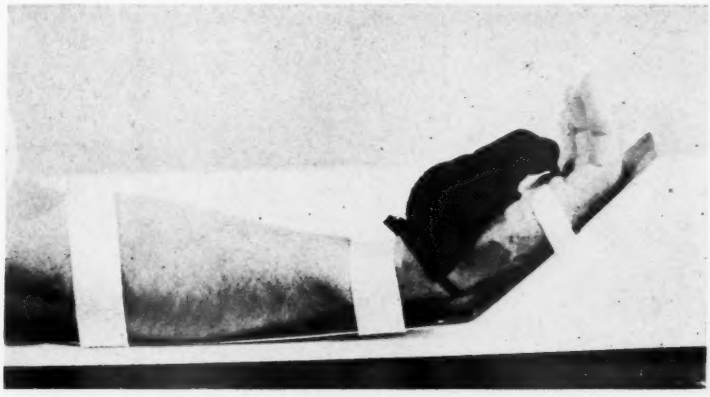


FIG. 10. Combination aluminum wrist-splint and thumb-cot. This combination is used in the early convalescence following neurorrhaphy of the ulnar nerve, median nerve, or both nerves at the wrist or root of the palm. Felt lining of metal splint has been omitted.

Neurorrhaphy in Fresh Wounds. Operative trauma should be minimal. This implies careful preoperative diagnosis, adequate exposure, and gentle and deliberate technique. Attempting to effect a repair through the original traumatic wound almost always necessitates rough handlings of tissues. A generous incision should be made. In dealing with fresh wounds no tourniquet is used. Slight proximal or distal pressure suffices to control bleeding until the incision has been made through the skin and fascia. Vessels are then secured. Practically no further bleeding is encountered.

At the volar aspect of the wrist severance of the median or the ulnar nerve is rarely an isolated lesion. Tendons are usually coincidently divided. (Figs. 2, 3 and 4.) In an extensive wound in this situation both nerves and most of the tendons may be damaged. When the operative approach is completed, the wound margins are retracted. Nothing is disturbed. The structures are studied in situ and identified. The median nerve is recognized by its grayish color, its tiny anterior vessel, its fibered ends and its position. At the wrist it lies just beneath and lateral to the palmaris longus tendon. If the latter is absent, the nerve is very superficial. Distally it lies just beneath the annular ligament. The ulnar nerve is recognized by its fibered ends and its position, at the wrist immediately lateral to the flexor carpi ulnaris tendon and distally anterior to the annular ligament skirting the pisiform. The proximal and distal ends of the

median and ulnar nerves are turned out of the wound and wrapped in small sponges soaked in warm saline solution until the coincidently severed tendons have been sutured. The nerve ends are

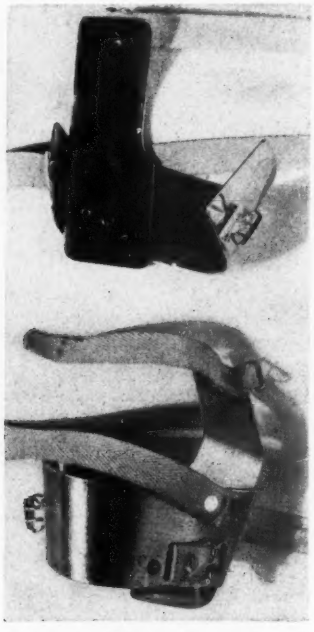
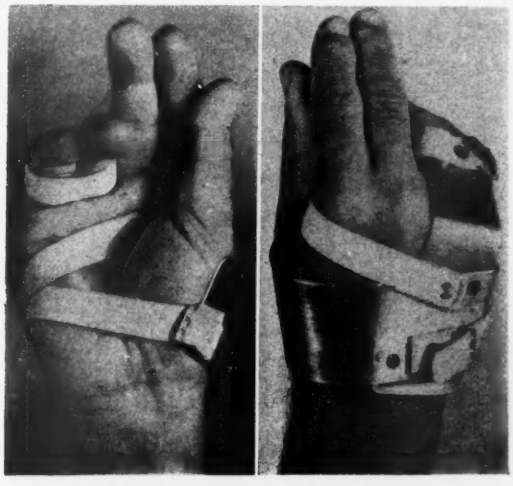


FIG. 11A. Flanged cross hand splint of aluminum used in later treatment of ulnar neurorrhaphy or ulnar and median neurorrhaphy at the wrist or base of palm.

then turned into position. If frayed, they are cleanly cross-sectioned with a sharp knife. The wrist is held in a flexed position. The edge of the sheath of the proximal end of the median nerve, close to its little volar vessel, is pierced with a tiny curved needle and the silk drawn through. The needle is then passed through a homologous point in the sheath of the distal end. The sectioned surfaces are moistened with salt solution from a medicine dropper and the suture is carefully tied so as to approximate the little vessel. By this procedure the nerve is brought together without twisting. The stitch ends are clipped in a small hemostat which is used to steady the nerve while a second stitch is placed through the sheath on the opposite side of the vessel.* Before being tied, the nerve ends are again moistened with a few drops of saline. These stitches are also clipped in a snap which is used to rotate the nerve so that a stitch

* In order to avoid bruising the nerve while the first stitch is being placed, it may be found helpful to steady it gently with a saline soaked cotton pledget held in a snap.

may be placed on the side of the nerve and tied under saline drip. In this manner the circumference of the median nerve is approximated by five or six sutures. The epineurium should be nicely



B C

FIG. 11B AND C. The flanged cross hand splint in use. The metacarpophalangeal flange prevents undue stretching of the hypothenar muscles (ulnar). The thumb flange similarly protects the thenar muscles (median and ulnar). The medial flange steadies the hand in the splint. It is lined with felt or applied over a glove from which middle and distal phalanges have been cut. It is readily removable for washing.

closed. No gaps should be left unclosed. The ulnar nerve is similarly repaired, but twisting must be avoided as much as possible without the guide of a tiny vessel. The suture lines of the nerves are *not* wrapped in fat. Flexion of the wrist is still maintained while the palmaris longus tendon is sutured, the annular ligament and fascia approximated with fine catgut, while the skin is closed with interrupted silk, and until a splint is applied. No drainage is used. If the wound is so soiled that drainage is necessary, immediate neurorrhapy (and tenorrhaphy) should not be attempted. This is a safe rule.

Such a wound should be cleansed and Dakin's treatment instituted. The sheaths of the nerve ends may be caught together with a stitch. This facilitates subsequent repair which should be postponed for some weeks after complete wound healing has occurred. The splint should be worn for a couple of weeks to minimize the retraction of the tendons. Until the repair operation is undertaken, joint stiffness and the stretching of atrophying muscles must be combated.

At the Root of the Palm. The term root of the palm is used to designate the interval between the proximal margin of the annular ligament and a line drawn on a level with the outstretched thumb. Many structures lie within this small compass. The author has seen injuries in this situation from falls on glass tumblers and bottles, a fall on a scythe, revolving blades of a wood fluting machine (Fig. 5) and porcelain faucet handles. Bones were transected in two instances. These accidents always present an exercise in anatomy and in surgical dexterity. Neurorrhaphy in this situation has been facilitated by magnifying lenses, by steadying the nerve with a saline soaked cotton pledget held in a snap, and by using tiny curved atraumatic needles.

In the Digits and on the Dorsum of the Hand. The digital nerves in the fingers show a remarkable propensity for regeneration. Restoration of function may require a considerable period of time, but in the author's experience if the edges of a fresh wound be carefully approximated, regeneration practically always occurs. This obtains, of course, only in wounds which heal by first intention. The author also believes that the digital nerves in the palm possess this same aptitude. This has been demonstrated in a number of cases of deep, stellate lacerations where, although no attempt was made to suture the digital nerves, complete restoration occurred. Since, however, these nerves carry motor fibers to the lumbricals it is better practice, if conditions permit, to search for them and approximate them with one or two sutures. This is especially important in case of the index finger.

The rami of the sensory branch of the radial nerve on the dorsolateral aspect of the wrist and hand, as well as the dorsal cutaneous branch of the ulnar nerve, should be sought and sutured. In skilled laborers and musicians, if the acute injury is not recognized, subsequent suture will be necessary.

Late Neurorrhaphy. Wide, delicate dissection through scar tissue is necessary for the identification and mobilization of structures. (Figs. 6 and 7.) A piece of rubber tubing to serve as a tourniquet is included in the kit. It is convenient to have at hand for temporary use in certain cases. In old ulnar nerve injuries at the wrist and root of the palm, for example, the vessels may have become converted into a plexus. A tourniquet, for a short time, greatly aids dissection and minimizes the trauma of sponging.*

* The author still prefers a sterile rubber tourniquet to a blood pressure cuff beneath the sterile drapes.

All scar tissue between nerve (and tendon) ends must be removed and the ends themselves prepared for suture by clean transection with a sharp knife. The proximal end of a nerve is usually sought first because it can be recognized by its "bulb." As the distal end possesses no characteristic marking, its discovery is less simple. The bulb is amputated. Tiny sections of the nerve ends are removed until both present normal appearing surfaces. This must be done conscientiously. The funiculi will be seen to extrude from the sectioned end. Fear of creating a sizable gap between nerve ends is, the author believes, the commonest cause of failure. *Nerve regeneration is impossible through scarred ends, regardless of the perfection of their suturing.*[4] The author also believes that end-to-end approximation without tension or twisting must be effected and has little confidence in the use of tubes (fascia, sections of veins, arteries, etc.) to bridge defects. Except in reconstruction of wrists and hands which have sustained wide tissue loss (see below) flexing the hand and elbow will usually be sufficient to permit suture at the wrist without tension. If not, the incision should be extended proximally and the nerve carefully freed for an appropriate distance. (Fig. 7.) If approximation cannot then be effected, in case of the ulnar nerve, the nerve may be transplanted anteriorly at the elbow. This has worked beautifully in five cases.*

Every effort, indeed, should be made to accomplish end-to-end suture without tension or twisting because the likelihood of success of this method of nerve repair so greatly exceeds that of all others. By securing the most favorable position of the digits of the wrist and elbow to shorten the space between nerve ends, by freely mobilizing the proximal and distal ends of the nerve or by transposition of the ulnar nerve at the elbow, the author in a considerable experience has never found it necessary to resort to free nerve grafting in the hand and wrist. In other regions gradual nerve lengthening by a two-stage operation[6,8] may overcome a wide defect

* In the December 1938 number of this Journal the author published his study of injuries to the hand, based upon 1100 personally treated cases, exclusive of minor cuts, abrasions, contusions, infections, burns and foreign bodies. The series included 138 cases of injury to nerves which form the basis of the present article. This recent analysis discloses five cases in which the ulnar nerve was transplanted anteriorly at the elbow to effect suture at the wrist instead of three as reported in the previous paper.[4] These are:

R. R. F 45 operated on Dec. 28, 1925 5 mos. after injury
H. W. M 17 operated on Dec. 21, 1927 12 mos. after injury
N. D. M 23 operated on May 21, 1931 14 mos. after injury
S. J. S. M 19 operated on June 27, 1931 23 mos. after injury
E. L. S. M 33 operated on Apr. 17 1933 5 mos. after injury

and obviate nerve grafting. The procedure has never been found necessary, however, in the hand and wrist.

In cases of maiming by old shotgun injuries or high voltage burns the correction of the contracture by some type of pedicle graft, later stabilization of the part by bone grafting, and the restoration of gross function by still later tendon grafting have so contented several patients that subsequent nerve grafting has not been desired. In multilating shotgun injuries to the hand, conservative surgery (thorough cleansing, debridement and dakinization, painstaking attention to the preservation of suppleness of the joints, followed by simple plastic procedures) has fortunately given functional recoveries exceeding primary expectation. Certain disabilities may be ameliorated by tendon transplantation and arthrodesis. Conditions requiring nerve grafting may, however, arise.* Although this procedure is viewed askance by some writers, successes have been reported in the field under consideration by several surgeons, notably Bunnell.[1,2] The use of a single section of nerve of the diameter of the injured nerve is preferable to several grafts of smaller diameter arranged as a cable. Careful closure of the epineurium at both ends is imperative. The graft serves, of course, merely as a conduit for the advancing neurofibrillae.

It has been suggested that the graft be sutured into the defect only at the proximal end and that it be somewhat longer than the defect. After a calculated interval of time the wound is reopened, the graft exposed and the distal end transected until the advancing neurofibrillae are encountered. The distal end of the injured nerve is then appropriately prepared and sutured to the lower end of the graft. The author has had no experience with this procedure. It is designed, of course, to thwart a possible scar tissue obstruction at the distal junction.

In cases with partial palsy in which improvement has not occurred following the use of appropriate measures to favor spontaneous regeneration, operation may disclose the nerve roughened to greater or lesser extent by fibrous adhesions, and perhaps somewhat thickened. This creates a problem of not infrequent occurrence. A decision must be made between neurolysis with or without endoneurolysis and resection with suture. The relative duration of the

* The author has bridged a gap of 3½ inches in the common peroneal nerve by a graft from the sural nerve. There has been perfectly satisfactory regeneration through the deep peroneal nerve but not through the superficial peroneal nerve. This may be due to discrepancy in the size of nerve end graft. Apparently, however, no lateral neuroma has developed.

convalescences following the two procedures renders the decision still more difficult. The history as regards date and nature of the accident, the age and occupation of the patient, and the extent of the palsy may be determining factors. Information of only gross nature can be ascertained by electrical stimulation of the nerve proximal to the pathology. When in considerable doubt the author prefers neurolysis with or without endoneurolysis. If it succeeds much time has been saved. If it fails a resection can subsequently be performed. The use of undamaged contiguous muscle or pedunculated fat grafts to protect the nerve from further adhesions is rarely practicable in the wrist and hand. Free fat is of doubtful benefit. The use of a membrane for this purpose has been too infrequent to warrant judgment as to its merit.

When a *lateral neuroma* is removed, the naked area should be covered with epineurium. To effect this without constriction of the nerve, a pedunculated strip of sheath may be carefully raised from the neuroma. After the clump of neurofibrillae entering into the bulb have been drawn tense and divided, the flap is caught over the defect with a couple of tiny silk sutures.

Splinting. After every neurorrhaphy a splint should be used. If the sutured nerve contains motor fibers, the splint should serve three purposes: (1) It should prevent tension on the suture-line to facilitate regeneration. (2) It should protect the muscles supplied by the injured nerve from being stretched by the pull of antagonistic muscles. (3) It should leave free for active use as much of the hand as possible. To prevent tension on the suture, the splint, as a general rule, should maintain the part in the position in which the suture was effected. If, for example, it was found necessary at operation to flex both the wrist and elbow to effect the suture without tension, the splint should maintain this position. This may be accomplished with a moulded plaster gutter. For immediate neurorrhaphy at the wrist a device for maintaining flexion of the wrist alone is usually sufficient. A simple, felt-covered aluminum splint* with appropriately placed buckle straps has been found satisfactory. (Fig. 8.) This splint also permits the early use of tendons which must often be coincidently repaired. By slightly angulating the splint at the knuckles, strain on the hypothenar muscles, the lumbricals, and the palmar interossei may be relieved. With early gross movements of the fingers this second angulation at the knuckles may not be deemed necessary. It may, moreover, have the disadvantage of

* For old injuries, in which deviation of the fingers has occurred, side flanges, with or without interdigital flanges, may be advantageously added.

straining the dorsal interossei in ulnar nerve injury. In connection with the wrist splint the author uses a suede thumb-cot. (Fig. 9.) This simple device effectively protects the atrophying superficial thenar muscles in case of median nerve injury and the deep muscles in case of ulnar injury.

This combination of wrist-splint and thumb-cot (Fig. 10) is worn for two months. If it is taken off occasionally by the surgeon and the wrist and thumb gently moved, no stiffness will occur. After this lapse of time nerve regeneration should have sufficiently progressed to withstand tension at the wrist. The second and third desiderata still obtain to prevent the stretching of atrophied muscles and to leave as much of the hand as possible free for exercise. In case of *median neurorrhaphy* use of the thumb-cot alone is then continued for some weeks. During this period the patient is supervised in exercises in apposition and abduction of the thumb and in extension of the middle and distal phalanges of the index finger. The time when the patient may be permitted to remove the cot himself for these exercises is determined, of course, by his intelligence and his spirit of cooperation. Although the thumb-cot does not support the lateral lumbrical muscle, the author has not seen any permanent impairment of extension of the middle and distal phalanges of the index finger.

After removal of the wrist splint and thumb-cot combination in case of *ulnar neurorrhaphy* or of both ulnar and median neurorrhaphy, the author uses a flanged-cross hand splint. (Fig. 11.) This splint is worn for twelve or sixteen weeks. During this period if the ulnar nerve alone has been sutured, the patient is supervised in exercises in abduction and adduction of the fingers, flexion of the fingers as rods at the metacarpophalangeal joints, extension of the middle and distal phalanges and in adduction of the thumb. If both median and ulnar nerves have been sutured, exercises in apposition and abduction of the thumb and in extension of the middle and distal phalanges of the index finger are added. As the muscles develop and the breadth of the hand increases, a similar but wider splint may be required. Here, again, the time when the patient may be permitted to remove the splint himself for exercises is determined by his intelligence and his spirit of cooperation. Although the flanged-cross hand splint does not definitely support the first, second, and third dorsal interossei, the first palmar interosseus, and the lateral lumbricals, the author has seen no permanent impairment of function of these muscles. This happy circumstance may be attributable to personal supervision. He has occasionally been

disappointed by some persistent weakness of the third palmar interosseus, as though it had been stretched by the more powerful abductor minimi digiti, leaving a slight interval between the ring and little fingers. This might be obviated by providing the metacarpophalangeal flange with a medial flange instead of depending wholly upon a buckle strap. (Fig. 11B.) The author has never been aware of any functional impairment attributable to pressure of the buckle straps. The straps, of course, must not be too tightly applied. On the contrary, as noted above, as a hand increases in breadth, a similar but wider splint becomes necessary.

After-Care. The more closely the operative technique approaches the ideal, the greater will be the likelihood of restoration of function. The postoperative course, however, cannot be left to chance. Quite as important as the operation is painstaking attention to details in the after-care. This cannot be too strongly emphasized. The convalescence is long. Thorough periodic examinations are necessary for several reasons: to detect the slightest evidence of progress, to determine the changing needs of muscle support and muscle exercise, to maintain the morale of the patient and to stimulate his coöperation. There can be no fixed rules. Each individual is a law unto himself.

Although nerve regeneration may be expected at the rate of a millimeter a day, the speed of regeneration may vary in the different branches of a given nerve. In following the progress of regeneration of a mixed nerve, motor tests are more reliable than sensory tests. Effort should be made to detect contraction in the muscle bellies and to avoid the deception of supplementary motility. The interpretation of tests for protopathic and epicritic sensibility should be conservative. The pitfalls of sensory overlap must be avoided. Tinel's sign has been found very suggestive especially when performed as a series of blunt pressures along the course of the nerve rather than by percussion.

At each visit the splint is removed and with the hand and wrist appropriately supported all of the muscles are tested individually and coördinately. The mobility of joints is maintained, if necessary, by massage and gentle passive motions. In due time the patient is permitted to remove his splint several times a day to perform certain exercises. At each subsequent visit special instructions are then given. Later he is encouraged to perform small tasks (with light tools, nails, screws, practicing on a musical instrument). Although in other regions of the body electrical stimulation of atrophied muscles is practiced, the author does not employ it in the hand.

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DISCUSSION

Henry C. Marble (Boston): It is needless for me to comment upon this work that Dr. Harmer has told us about. It is a beautiful exercise in anatomy and surgical technique, and the results he showed here speak for themselves.

There is one question I want to ask him that he did not take up. Perhaps it isn't pertinent. How does he handle gross defects of nerves, such as an inch and a half or 2 inches lost from the median nerve?

There is one other phase that interests me just at the moment, and that is in the matter of painful scars and neuromata. In the past we have made an effort to prevent them by injection into the nerve with alcohol. The results have not been particularly satisfactory. For about two years I have been injecting these nerves with ether. The pathologists tell me that ether has one advantage. It dissolves the myelin sheaths very completely and if this is done, the neuromata will be less painful and less incapacitated. My personal experience has been that the anesthesia produced from injecting ether into the nerves is complete and prolonged.

Torr W. Harmer (closing): I wish to thank Dr. Marble for his discussion of my paper. In order to bring the discussion of the paper within the allotted time, I have deleted a number of passages which will appear in the printed article. These answer in detail the first and last questions which Doctor Marble asked. In view of the lateness of the hour I pray you and he will excuse me if I refer you to the published paper.

I may state briefly that, as you all know, free mobilization of the proximal and distal ends of the median nerve combined with flexion of the wrist, fingers and elbow will on most cases admit end-to-end suture without undue tension. In wider defects gradual lengthening with secondary suture, as suggested by Naffziger, Pollock and Davis, may be practiced. The technique of nerve grafting is too long a subject to discuss here. Suffice it to say that a free graft of the diameter of the injured nerve is much more likely to serve as a satisfactory conduit for the advancing neurofibrillae than a cable of several sections of lesser diameter. The graft may be sutured to both ends of the defect or a section longer than the defect may be sutured first at the proximal end and, after a calculated interval of time, suture at the distal end may be completed.

I am interested in Dr. Marble's remarks about smelling his novocaine before he injects it and about using ether instead of alcohol for the injection of neuromata in amputation stumps. In the treatment of terminal neuromata I practice excision, with section of the nerve well above the bulb. In finger stumps this may be fussy work but can usually be satisfactorily accomplished under novocaine or evipal with the aid of magnifying lenses which clasp over spectacles, as shown in the first illustration. I shall be interested to try the injection of ether instead of alcohol in cases of causalgia.

In regard to Dr. Marble's last question: It is my understanding that the extensor tendons of the fingers with their muscle bellies supplied by the radial nerve extend the fingers at the metacarpophalangeal joints, but that the burden of the extension at the middle and distal joints falls upon the interossei supplied by the ulnar nerve and the lumbricals, the two lateral supplied by the median and the two medial supplied by the ulnar. Extension of the middle and distal phalanges of the index finger is accomplished, I believe, wholly by the first lumbrical, despite the two extensor tendons. The middle finger possesses two interossei and one lumbrical and the ring and little fingers one each, with, of course, two extensor tendons in the case of the little finger. The third lumbrical going to the ring finger has often a double nerve supply (median and ulnar), and there may be an anastomosis between the deep branch of the ulnar and the median at the root of the palm.

KNEE INJURIES INCIDENT TO SPORTS AND RECREATION

AUGUSTUS THORNDIKE, JR., M.D., F.A.C.S.

BOSTON, MASSACHUSETTS

IN addressing this association whose main interest is trauma, it occurred to the author that perhaps to date too little interest has been devoted to trauma produced in sports and recreation. Most of our medical colleagues caring for traumatic injuries see mainly those cases that arrive in our hospitals with the more serious traumatic lesions. There is, however, a large and ever-increasing field of lesser and yet important trauma occurring among those individuals who enjoy sports and recreation.

The interest in sports among old and young is worldwide. It has been estimated that over eight million participate in school, college and professionally organized sports in this country alone. Furthermore, over a million sport lovers indulge informally in gold, tennis, mountain climbing and skiing. Frank Mencke[1] informs us that the interest of followers or spectators in organized sports in the United States reached these remarkable totals last year: basketball, ninety million; softball, seventy-two million; baseball, sixty million; football, forty-five million. Nor is this peculiar to our own country! A recent Associated Press dispatch recorded 150,000 spectators at the championship soccer game between England and Scotland.

Most of these players experience some injury, usually minor, but occasionally serious in nature. Our interest has not been focused sufficiently on simple strains, sprains and contusions. Furthermore, in general, the treatment such injuries receive at the present time is inadequate. Today knee joint traumata have been selected to emphasize adequate treatment of all types of injuries, in order that recurrent or additional more serious injury may be prevented later.

When trauma to this joint is seen within a few seconds of the time of injury, rather than an hour or more later, there are certain definite points concerning diagnosis and treatment that might be of interest. There are few of us who have the opportunity of seeing this particular phase. It is of further interest in that adequate treatment promptly instituted will benefit the patient.

To understand the results of trauma to this joint, a thorough knowledge of the pathologic picture is essential. Little emphasis has been placed on this, but much should be. If either a joint or bursa

contusion, muscle (vastus medialis) contusion, sprain, or partial luxation of the joint surface, with a tear or loosening of the menisci and capsule takes place, certain definite events follow in quick order. In each and every one of these types of injury, there is always concomitant hemorrhage from torn areolar tissue, blood vessels, and capillaries, whether within or without the synovial membrane. Hemorrhage promptly takes place, in addition to the tearing of specialized tissue. During the process of repair, one expects in sequence hematoma formation, hematoma absorption and healing by fibroblastic repair. Such, then, in brief is the pathology of the trauma and its repair. The problem is to estimate promptly the extent of the lesion or lesions and institute immediately the appropriate and adequate measures to control and protect first the tissues torn, and second the hemorrhage and hematoma.

The diagnosis of the contusions, sprains, and possible internal derangements at the time of injury is difficult. The picture is utterly different from that seen one hour or more afterwards! There is but one way to proceed with the examination. First, palpate the bony prominences, the areas over the vasti muscles and over the ligaments, to elicit points of tenderness, if any. Second, with the muscles relaxed, test for ligament weakness by gentle manipulation, searching for abnormal lateral, medial or anteroposterior mobility. And third, test active muscular function for flexion and extension. Three such points taken in sequence will reveal a provisional diagnosis. It is not wise to give a final diagnosis until the patient is seen the following day, after the first and most important phase of the treatment has been carried out. Then repeating the three steps of the examination, a more accurate diagnosis both as to type of injury and degree of injury and probable prognosis as to period of convalescence can be made. Reserve prognostication always until twenty-four hours after such an injury!

It is needless to describe the accurate points of palpation and the function tests to be carried out to diagnose either a sprain of the medial collateral ligament or a joint capsule contusion or a meniscus injury. They are known by all surgeons interested in trauma. The frequency with which these different types of injuries occur in organized sports is given in Table 1. The striking feature, I believe, is the low incidence of internal derangements among these 483 cases (less than 10 per cent). This is attributed to treatment and especially to subsequent prophylactic treatment. A firm conviction that menisci are rarely injured with the first sprain of a knee holds the attention of my entire staff. To be sure, it occasionally happens when

the trauma is severe enough to tear the joint capsule, but this is most unusual and accounts for only three cases (one of these never

TABLE I

KNEE JOINT INJURIES IN ORGANIZED SPORTS OVER A SEVEN YEAR PERIOD AT HARVARD UNIVERSITY

(Exclusive of lacerations and other less serious injuries)

Ligament sprains	203
Joint contusions	145
Muscle contusions	78
*Internal derangements	43
Bursa contusions	8
Superficial contusions	6
Total	483

* Inclusive of all meniscus and crucial ligament injuries.

developed a meniscus injury, in spite of the capsule tear). These sprains are analyzed in Table II to show the particular ligaments involved, in a series of 246 sprained knees.

TABLE II

KNEE SPRAINS IN ORGANIZED SPORTS AT HARVARD UNIVERSITY

Ligaments Involved	1932–1933	1933–1934	1934–1935	1935–1936	1936–1937	1937–1938	1938–1939	Totals
Medial collateral ligament	37	21	26	16	18	20	11	149
Lateral collateral ligament	4	2	7	8	4	7	0	32
Crucial ligament	4	4	2	0	0	3	0	13
Medial collateral ligament and medial meniscus	5	8	2	7	0	0	1	23
Medial collateral and lateral collateral ligaments	0	2	0	1	2	1	0	6
Medial collateral ligament and lateral meniscus	0	0	0	1	0	0	0	1
Medial collateral and crucial ligaments	0	1	0	3	0	1	0	5
Lateral collateral and crucial ligaments	0	0	0	0	0	0	0	0
Lateral collateral ligament and medial meniscus	0	0	0	0	0	0	0	0
Lateral collateral ligament and lateral meniscus	0	0	1	0	0	0	0	1
Tibiofibular ligament superior	0	3	0	0	0	0	0	3
Patellar ligament	0	1	0	0	0	0	0	1
No ligaments mentioned	4	3	2	1	0	2	0	12
Totals	54	45	40	37	25	34	12	246

The total individual ligament sprains are recapitulated in Table III.

The treatment of knee injuries divided itself into three different periods: (1) Early treatment, (2) convalescent treatment, and (3) prophylactic treatment to prevent a recurrence of the injury. Rarely is the opportunity presented to see these injuries immediately after they take place, the optimum moment to start treatment.

Recalling the pathology of contusions and sprains, the immediate treatment is aimed toward the control of hemorrhage and the

TABLE III

LIGAMENTS INVOLVED IN KNEE SPRAINS

Medial collateral ligament	149
Lateral collateral ligament	32
Medial collateral ligament and medial meniscus	23
Crucial ligament	13
Medial collateral ligament and lateral collateral ligament	6
Medial collateral ligament and crucial ligament	5
Tibiofibular ligament, superior	3
Medial collateral ligament and lateral meniscus	1
Lateral collateral ligament and lateral meniscus	1
Patellar ligament	1
Unspecified	12
Total	246

minimizing of the hematoma. There are only three steps to this: (1) the application of cold, preferably ice water for one hour, followed by (2) the application of a compression bandage, utilizing sponge rubber, and (3) rest. These are the immediate measures to control subsequent fluid or blood accumulation in or about the joint. When these measures are carried out promptly, one rarely sees "water on the knee" as an accompanying complication in sprains and contusions. The sponge rubber compression yields good results. When the bandage is first removed, twenty-four hours after its application, ecchymosis is evident at the margin of the rubber pads. This represents deep hemorrhage controlled and forced by compression from the deeper tissues into the skin. Once brought to the superficial tissues, its absorption can be more effectively treated by massage. The hematoma is dispensed with, and there is little or no fluid in the joint. The joint capsule is not distended the day following the injury. In the most severe primary injuries with tears of the ligament and capsule, when more than 10 degrees of abnormal mobility is elicited in the first examination, the early treatment is instituted as usual. However, a light cylindrical cast is applied outside the compression bandage, and the patient is hospitalized with the leg elevated on three pillows for forty-eight hours. Even in such cases joint effusions are exceedingly rare.

The convalescent treatment is aimed to promote the absorption of the hematoma and waste products of hemorrhage and to hasten the tissue repair. The two agents resorted to for stimulation of

FIG. 1. The use of sponge rubber in a compression bandage of the knee. (From Thorndike's "Athletic Injuries," Lea & Febiger.)

lymphatic absorption are *heat* and *massage*. At first these are applied proximal to the site of trauma, and at about the fifth to seventh day actually on this site. Vigorous massage is always contraindicated, and only gentle stroking and effleurage should be tolerated. Between treatments, the sponge rubber compression bandage is worn, and weight bearing and physical activity gradually permitted. No longer is joint effusion a complicating factor, and no longer is withdrawal of fluid by needle and syringe necessary.

The patient is not permitted to return to sports or recreation until muscle tone has returned to normal and until all tenderness in the ligaments or contused tissues involved has disappeared, and then only with a restrictive adhesive strapping and padding to prevent

FIG. 2. Ecchymosis visible in the skin twenty-four hours after the injury at the margin of the rubber pad.

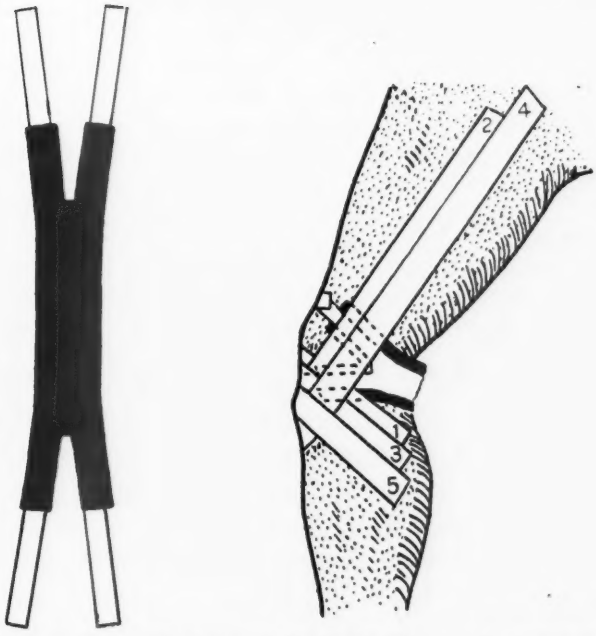

FIG. 3. Basic principles of the Duke Simpson knee strapping. (From Thorndike's "Athletic Injuries," Lea & Febiger.)

recurrent injury. This prophylactic period of treatment is most important and should continue always, particularly in sprains. Ligamentous tissues heal by fibroblastic repair, always remain weak or "brittle," and cannot withstand the stress or strain of a normal ligament. "Once a sprain, always a sprain."[2] The prophylactic strapping is indicated from then on in future years. It is more frequently in the recurrent sprain that the meniscus and other internal structures of the knee are injured. Many high school boys with sprained knees have been carried through a college athletic career without recurrent sprains by careful adherence to this régime. Many a serious internal derangement of the knee has been prevented.

For the last seven years, with ever-increasing success, this method of treatment has been carried out in a series of 246 knee sprains. The results are gratifying; the recurrent injuries and the more serious internal derangements of the knee are becoming less frequent. Last autumn on the Harvard varsity football squad of thirty-five men, there were sixteen knees previously sprained that were prophylactically treated daily for eleven weeks of play. Only one of these experienced a recurrent injury, and that a mild one. The steady decline in the number of more serious injuries proves the value of any treatment.

TABLE IV

RATIO OF SERIOUS KNEE INJURIES IN ORGANIZED SPORTS AT HARVARD COLLEGE

	1932–1935, Incl.		1935–1938, Incl.		1938–1939*	
	No.	Ratio	No.	Ratio	No.	Ratio
Knee sprains	110	11	77	8	11	11
Internal derangements	29	3	19	2	1	1

* Through April, 1939.

CONCLUSIONS

1. The adequate treatment of knee injuries incident to sports and recreation requires the institution of early and prompt diagnosis, and immediate application of cold, compression bandage, and rest, to control hemorrhage and protect the injured tissues.

2. During the convalescent treatment, measures are instituted to promote the absorption of the waste products of hemorrhage, and to stimulate tissue repair.

3. All former sprains should be protected by adhesive strapping to prevent a recurrence of such injuries in sports or recreation where stress and strain are expected.

4. The steady decline in the ratio of serious internal derangements of the knee joint among knee sprains in organized athletics is proof that this treatment is of value.

REFERENCES

1. MENCKE, F. G. Cyclopedia of Sport. New York, 1939. Privately Printed.
2. THORNDIKE, AUGUSTUS, JR. Athletic Injuries, Philadelphia, 1933. Lea and Febiger.

DISCUSSION

HENRY H. RITTER (New York City): It was a great privilege to listen to Dr. Thorndike's very able discussion of knee joint traumata in sports and recreation. He has an opportunity that is afforded very few of us, of seeing these accidents immediately after they occur, of treating them immediately, and following them through their entire course. The results he has shown are evidences of intelligent, intensive, and early treatment. I envy him his position.

The cases of sport injuries to the knee that come to me usually appear some time after the occurrence of the accident and are mostly in the older people than those seen by Dr. Thorndike. The majority are men in the employ of the larger corporations which further sports among their employees, or in children from the city playgrouns. The games are baseball, basketball, bowling, and, to a lesser extent, football. When the patients get to me, as a rule, the knee joint is swollen and there is fluid within the joint, but I rarely ever see them until many hours or days after the accident.

Dr. Thorndike has shown us the marvelous reduction in the number of sprains to the knee joint in football accidents. I did not quite understand whether that was because of the pre-sport examination of candidates for the teams or whether it was the result of excellent coaching or splendid training, or a combination of all three.

Our percentage of injuries to the meniscus, and particularly the medial meniscus, is somewhat higher than his. That may be the result of dealing with older people who work all week, are not well coached and not well trained, or due to the fact that we do not have all accident cases reported if they are apparently of a minor nature. Dr. Thorndike's number is extremely small.

We agree that the medial meniscus is the most commonly damaged; we agree that the median collateral ligament is the most commonly involved.

Recently a man who is associated with one of the larger teams told me that no matter how trivial they are, he immobilizes knee joint injuries for a period of two or three weeks. He starts with passive motion, but I mention that only to condemn it. I see nothing passive about passive motion except the name. There is nothing passive about a doctor manipulating a painful knee while the patient screams and yells in pain. Any time such a thing as passive motion is necessary, I think it should be done under anesthesia.

A patient of mine, a girl 13 years of age, who was on the track team of a boarding school, was high jumping when she injured her knee. Forty-eight hours later, she was brought to me. The knee joint was swollen, painful, and tender. A small body was noted by *x*-ray in the intercondyloid notch, that piece of bone that comes from the articular surface of the lateral condyle of the femur. It was a fracture of the cartilage and bone.

The patient was sent to the hospital and prepared. On the following morning, through a lateral incision, I opened the knee joint and found the joint full of blood which was evacuated and we removed the specimen. We immediately had her move the knee, the afternoon of the same day. On the fifth day, she was out of bed and on the seventh day, she was walking about. Two weeks after her operation she could keep the knee completely extended. She engaged in sports three momths after the operation.

In another sports accident, the patient was a rather stout lady who wanted to do some skating to keep down her weight. She fell and sustained an anterior dislocation of the leg which was very easy to reduce. She had no restraining apparatus and no cast applied. She developed pneumonia on the afternoon of the second day, stayed in bed for some weeks, and when she got up, she was able to bend the knee to a right angle and extend it to a straight angle.

A young lad who played on the baseball team of one of the gas companies in our state had had an accident eight months before. He was sliding into base, and his knee locked on him. On the following day, I saw him. A foreign body could be observed in the *x*-ray and a depression in the condyle from which the body came. The diagnosis was osteochondritis dissecans. I did not think it had anything to do with the accident. During the examination, I found that the opposite knee had been operated upon. We got in touch with the hospital where the operation was performed and they sent us all the radiographs made at that time of the operation. An *x*-ray taken eight months before the alleged accident showed a typical osteochondritis dissecans, not separated. We removed the loose body. There was no hemorrhage. It was perfectly smooth and was not bleeding. There was no evidence of trauma.

Edgar L. Gilcreest (San Francisco): The thing that interested me most was Dr. Thorndike's statistics showing that the ligaments were injured the greatest number of times, the joint surfaces second, and the muscles third.

I have been particularly interested in these lesions of muscles for fifteen years. I have seen many patients with muscle tears who have gone for a considerable length of time, having pain referred to their joints, and who were given various forms of treatment to the joint itself, but when the muscle was repaired, they would become well and would return to work 100 per cent recovered, often within three months after the operation. I

would like to ask Dr. Thorndike, if he has found many of these lesions of muscles near the joint?

AUGUSTUS THORNDIKE, JR. (closing): I wish to leave you with the impression that these statistics were taken from all sports and not only from football. The reduction in the number of sprains, of course, is partly due to better training. It is also due to the fact that we now strap all the formerly sprained knees. At the beginning of this period, those boys who were taking part in the intramural athletic program (not intercollegiate), were not strapped. Now, however, they receive exactly the same treatment and care as our varsity. Therefore, more people are being protected against recurrent sprains than used to be.

The question of immobilization of knees—the only knee injuries we immobilize are those presenting 10 degrees abnormal mobility or more, or a tear of the capsule. We do immobilize them forty-eight hours in bed with the leg elevated. We split the cast after forty-eight years, and find no effusion in the joint. We start them on crutches and gradually make them walk and give them physiotherapy beginning the following day.

I do not believe that passive motion or forceful motion should ever be attempted on this type of injury.

Osteochondritis is a very interesting thing. We have not seen a single instance of it in boys of college age. I know it happens, but they just have not drifted into our clinic.

As to Dr. Gilcreest's question on lesions of the muscle, I take it he means a tear of the quadriceps fascia and a muscle herniation following it. The pain may be referred to the knee. We have had none of those in the thigh since I have been responsible to the athletic teams, but I know of several men my age who received such injuries in college football, where the fascia was torn over the quadriceps and the muscle protruded through the fascial tear, presenting a true muscle hernia. I have seen it, however, in the lower leg in sprinters and hurdlers, causing a good deal of discomfort. Repair, of course, relieves the symptoms.

BOOK REVIEWS

A TOPOGRAPHIC ATLAS FOR X-RAY THERAPY. By Ira Kaplan, M.D. and Sidney Rubenfeld, M.D. Chicago, 1939. Year Book Publishers, Inc. Price $5.00.

With the modern advances in the use of radiation therapy, particularly in malignant disease, but also in a wide variety of less serious lesions, a guide for the therapist to the anatomic landmarks of internal structures is a manifest necessity. Dr. Kaplan, head of the department of radiation therapy at Bellevue Hospital in New York and director of the division of cancer of the New York City Department of Hospitals, has, with the collaboration of Dr. Sidney Rubenfeld, now presented such a tpoographic atlas.

The book consists of a series of plates, showing the projection of internal organs on the body surface, their relationships to visible and palpable landmarks, and the proper situation of radiation cones for treatment directed to these organs. The explanatory text gives suggestions for placing the cones with regard to the external features, and describes the direction they are to take for particular therapeutic results. A particularly valuable feature is a series of plates showing the lymphatic drainage areas associated with those organs most commonly affected by cancer.

The drawings, excellent work by Evelyn Madsen, are clear and distinct, and are likely to be more helpful to the therapist than the *x*-ray films usually presented.

BEESLY AND JOHNSTON'S MANUAL OF SURGICAL ANATOMY. Revised by John Bruce, F.R.C.S. and Robert Walmsley, M.D. Fifth Edition. London, 1939. Oxford University Press. Price $6.50.

When the first edition of this work came out in 1918 it received excellent reviews and enjoyed a wide distribution. In this, the fifth edition, the entire text has been thoroughly revised, some new matter introduced and accounts of several surgical procedures which are no longer practiced omitted. The book is divided into six sections, covering the head and neck, upper extremities, thorax, abdomen and pelvis, lower limbs, and vertebral column. The illustrations (187) are above average, and the index is good. A book that goes into a fifth edition speaks for itself.

DISEASES OF THE FOOT. By EMIL D. W. HAUSER, M.D. Philadelphia, 1939. Saunders. Price $6.00.

Dr. Hauser has studied the foot from all angles and has written a thorough study based for the most part on his personal experience, with methods tried in practice. Since 1922, when Professor Richard Scammon placed at his disposal a large series of valuable fetal, newborn and children's feet for anatomic study, his work has continued. At the Mayo Clinic, the large volume of material in the orthopedic department gave an opportunity to study the diagnosis and methods of treatment of diseases and injuries of the foot. A year as American-Scandinavian Fellow afforded him the privilege of studying under Professor Patril Haglund in Stockholm, whose work on clubfoot and infantile paralysis is classic. Dr. T. P. Noble imparted to him the teachings of his chief, Sir Robert Jones. From this long training and experience the present book stems. The subject is thoroughly covered. The illustrations are good. It is interesting. Since foot ailments are a common and important source of physical disability, this book can be read or studied with profit by both the general practitioner and the specialist.

ROENTGEN TECHNIQUE. By Clyde McNeill, M.D. Springfield, 1939. Charles C. Thomas. Price $5.00.

Dr. McNeill has given us a technical book of interest to those concerned with the general subject of roentgenology. The illustrations are excellent and number 268. The book is well arranged and full of suggestions and information. Although there are many good books on this subject, this one may be recommended for its time saving qualities.